GAS TORCH

AND

THERMIT WELDING

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BY

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FIRST EDITION

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK: 370 SEVENTH AVENUE
LONDON: 6 & 8 BOUVERIE ST., E. C. 4
1921

PREFACE

THE beginner, the practical worker, the student and the engineer, will find in this book a great amount of information regarding gas-torch and Thermit welding practice and equipment. No toil or expense has been spared to gather material of real and lasting value. Shops have been visited and data and photographs obtained first hand. Practically every book on welding has been carefully scrutinized for helpful suggestions. The services of experts have been engaged to give the results of long practice and research in their special lines. Each and every plan known to the experienced editor has been employed to give the reader the highest possible grade of information.

The historical references have been cut to the barest statement of facts as we have been able to obtain them, yet they are ample enough to give the inquiring mind the genesis of each class. Foreign methods and equipment have not been touched upon, except in a few instances, because such treatment would add too greatly to the bulk of this work, without adding an appreciable amount to its real value, since the methods and standard equipment here are, in general, far in advance of anything similar elsewhere.

Great care has been taken to indicate the sources of information and to give the names and addresses of the makers of equipment shown. It is believed that every well known maker of this class of welding apparatus in the United States has been mentioned at least once in these pages. This has not been done with any idea of advertising them, but because it is information every reader is entitled to have without the necessity of making a separate search for it.

Of course no recommendations regarding the best apparatus to use are made in any case. As in any other line, improvements are being constantly made, but in regard to newly invented or unknown equipment the seller should be made to prove his case before an investment is made. Apparatus which does not meet the present day requirements, soon drops out of sight. It is a good plan for a prospective purchaser of equipment to consult some well established firm which is not afraid to advertise its product in open competition. Such a firm will see that its equipment is properly installed and works satisfactorily.

ETHAN VIALL.

New York City,
November, 1920.

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PART I—GAS TORCH WELDING

GAS TORCH AND THERMIT WELDING

CHAPTER I

HISTORY AND USES OF THE GAS TORCH.

According to common usage, the term "autogenous welding" is erroneously applied only to hot gas flame fusion welds. The gas combinations used for the production of the hot flame for welding or cutting are oxy-acetylene, oxy-hydrogen, oxy-thermalene or any combination that will produce sufficient heat, and is applied by means of a torch or blow-pipe. The welds so produced are strictly fusion welds, as no pressure or hammering is employed to effect the union. The word "autogenous" means "self-produced" or "self-generated," that is, joined with the same metal, and as such applies equally to hot gas flame, electric arc or thermit welds, although as just stated, the present custom is to apply the term generally to hot gas flame welds. However, owing to the wide field that the term "autogenous" really covers, and to the looseness with which it is often applied, we prefer to use the term "gas torch" in connection with welding and cutting by means of the hot gas flame.

While the use of a blow-pipe or torch in some form was known to the ancients, the high temperature gas flame is a development of the last quarter of a century. The more commonly known gas combination is oxy-acetylene. Acetlyene (C_2H_2) was discovered by Edmund Davy in 1836, but it remained only a laboratory gas until T. L. Willson of North Carolina and H. Moisson, the Frenchman, developed commercial methods of producing calcium carbide (CaC_2) in large quantities in 1891-92. In 1895 Le Chatelier read a paper before the Paris Academy of Sciences in which he stated that: "acetylene burned with an equal volume of oxygen gives a temperature which is 1000 deg. C. (1800 deg. F.) higher than the oxy-hydrogen flame. The products of the combustion are carbon monoxide and hydrogen, which are reducing agents." Further along he said: "this double property makes the use of acetylene in blow-pipes of very great value for the production of high temperatures in the laboratory." This statement of Le Chatelier is especially noteworthy, since he set the ratio of the gases at equal volumes, and not at the theoretical proportion of 2½ volumes of oxygen to 1 of acetylene.

The application of the oxy-acetylene gas torch to metallic welding dates experimentally from 1901, and industrially from 1903. Edmond Fouche, of Paris, who did considerable experimenting in conjunction with Picard, is generally credited with having devised the first really practical and safe torch. In February 1904 Fouche sent two of his torches to Eugene Bournonville, of New York, with which the latter repaired a machine that was still in use years later. The Fouche and Picard torch first developed, used both oxygen and acetylene under high pressure. There proved to be serious objections to this, and Fouche next produced the low pressure or injector type of torch which employed only the oxygen under high pressure. Following these was the Gauthier-Ely positive pressure or medium-pressure type which used both gases under moderate and independent pressures. This type was later brought to the United States by Augustine Davis and Eugene Bournonville in 1906. During this year Bournonville designed the first acetylene pressure generator produced in connection with the oxy-acetylene process.

In 1905 and 1906 considerable welding work was done but the process was handicapped by the inadequacy and poor quality of the oxygen then obtainable, and also by the imperfect knowledge and technique necessary to good work. In 1902, Carl Linde patented in England a process for liquefying air and producing oxygen and nitrogen. In 1906 a plant for the production of oxygen by the Linde process was established in Buffalo, N. Y. From that time on, oxygen plants of various kinds have constantly increased in number and the commercial production of oxygen of good quality has been a great factor in the development of gas torch welding.

At first, operations were limited to the simplest repair work on iron or steel. As the apparatus was improved and the efficiency of the welders increased, the field widened. New uses have been found for the process and the range of metals coming within its scope has steadily expanded. It has its limitations, however, which will be pointed out elsewhere.

Used for Both Welding and Cutting.—In addition to welding, the oxy-acetylene flame, as well as a number of others, is applicable to cutting. In fact so closely allied are welding and cutting in this field, that an operator is usually called upon to do both many times in a day's work. Cutting by means of an oxygen jet was first made commercially possible by Jottrand, who took his basic patent in 1905.

Aside from the manual operation of welding or cutting torches, a large number of machines have been designed. These range from simple wheel or radius attachments for the torch itself, to huge automatic pipe making machines or others of a complicated nature.

The oxy-acetylene flame consists of two parts, a small inner luminous "cone" which is bluish white in color, and a larger enveloping non-luminous flame. The temperature at the apex of the cone is estimated to be about 6300 deg. F. This heat is not surpassed by any burning gas with the possible exception of thermalene, for which 6500 deg. F. is claimed.

For welding purposes the high efficiency of acetylene is due to its high carbon content and to the fact that it is endothermic, that is to say, heat-absorbing in its formation. Energy stored up in formation is given off again in the form of heat by the acetylene upon dissociation. It is calculated that of 1475 heat units in a cubic foot, 227 are due to the mere breaking up of the gas. While theoretically two and one-half volumes of oxygen are needed to completely burn one volume of acetylene, the ratio in which the gases are employed in practice is about one volume of oxygen to one volume of acetylene. The flame yielded by such a mixture is the correct one, or the so-called "neutral" flame. By increasing or decreasing the proportion of oxygen, flames known as either oxidizing or reducing may be obtained, the appearance of the cone changing as the proportions are modified.

While the use of oxy-acetylene for welding is more commonly known than any other combination, there are several gases, which when mixed with oxygen, will produce more or less satisfactory welds. Some of them are to be preferred to acetylene for certain cutting purposes. The better known gases are described as follows, it being understood that they are to be used with oxygen.

Hydrogen gas is a chemical element which exists in nature in great quantities in various chemical combinations. The most common is its union with oxygen to form water (H_2O). As a consequence, water is used as a basis for making both oxygen and hydrogen. Oxy-hydrogen welding was the first gas torch welding system employed, and it was used quite extensively until the introduction of the more advantageous system of welding with oxy-acetylene. While hydrogen may be manufactured on the premises, it is also handled commercially in steel cylinders. In using this flame for welding there is an existing danger that the oxygen may unite with the metal causing it to be overheated or burnt. To prevent the burning of the metal, it becomes necessary to use a supercharge of hydrogen so that oxygen liberated within the flame will combine with the free hydrogen instead of with the metal. This, however, increases the size and decreases the temperature of the flame. The temperature of the oxy-hydrogen flame according to Kautny, can never go higher than the dissociation temperature of water, which is estimated at 2000 deg. C. (3632 F.) For welding thin metal sheets hydrogen is practical on account of its comparatively low heat. The quality of the weld, however, decreases as the thickness of the metal increases. While theoretically only two volumes of hydrogen are required to one of oxygen, in actual practice when employing an oxy-hydrogen torch, it is necessary to use four or five volumes of hydrogen to one of oxygen in order to insure a non-oxidizing flame. This in itself is a wasteful process, since the maximum heat obtained is limited to the amount produced by combining two volumes of hydrogen to one of oxygen. For heavy cutting it is preferred to acetylene on account of its longer flame. It is also used extensively for lead burning, preheating, soldering, brazing, annealing, special forging or rivet heating and a number of other things.

Thermalene is one of the latest gases to be produced. It is the discovery of Linus Wolf, Zurich, Switzerland, and it is handled in this country by the Thermalene Co., Chicago Heights, Ill. It is a combination produced by the decomposition of calcium carbide and hydrocarbon oils, the heat generated by the carbide being used to vaporize the oil. It is used for either welding or cutting.

Blaugas is a liquid under pressure. It is the discovery of Herman Blau and it is made from gas oil, a product of the oil refineries. It probably has the lowest explosive range of any gas used for illuminating purposes, the range being about 4 per cent while that of coal gas is about 13 per cent. Like coal gas, however, it is little used for welding, though sometimes used for cutting. Blaugas is marketed in steel cylinders having the equivalent of 1300 cu.ft. of city gas, by the American Blaugas Corp., New York. Its largest field is for cooking and lighting purposes where coal gas is not readily obtainable. Owing to its portability it may be used to advantage for preheating work.

Drigas is a light oil gas, which is a vapor under pressure. It is sold in steel cylinders of about 150 cu.ft. by the same concern handling blaugas. It is especially good in combination with oxygen for cutting metal from 1 to 12 in. thick, and is also considerably used for preheating. Its explosive range is about $\frac{1}{3}$ that of coal gas, and it is non-poisonous and non-asphyxiating.

Illuminating Gas (coal gas or water gas) can only be used for welding very thin pieces owing to the low temperature of the flame. It may, however, be used for preheating or cutting.

Benzine or Benzol Vapors have the same properties, approximately, as blaugas. The temperature is a little higher than that of illuminating gas, but much lower than acetylene. It is only used for welding under special circumstances.

While a number of gases, which are used with oxygen, have been mentioned, only the production and use of hydrogen, acetylene and thermalene will be described, along with that of oxygen.

Explosive Limits of Welding Gases.—In order to be explosive, a combustible gas or vapor must be mixed with a certain amount of oxygen or air, the proportions of the mixture ranging between certain limits depending on the character of the fuel. Any figures showing these explosive limits of the gases can only be approximate at best, since so many things enter into the calculations, such as the purity of the gas, means of ignition, temperature, pressure, and so on. In general, the mixture that has just enough oxygen for complete combustion of the fuel gives the highest pressures and temperatures, and very nearly the highest speed of ignition. If the proportion of oxygen (air) is increased beyond, or decreased from, the theoretical proportion, the maximum pressures and temperatures are lowered and the speed of ignition decreases until at certain upper and lower limits the mixture ceases to be explosive, and only slow combustion can occur.

The figures here given are believed to be a fair average of those given by the various authorities. The explosion is supposed to be caused by an electric spark, at atmospheric pressure and a temperature of about 65 deg. F.

Acetylene—3 per cent gas plus 97 per cent air to 55 per cent gas plus 45 per cent air, or a range of 52 per cent (one writer says 73 per cent gas plus 27 per cent air).

Blaugas—4 per cent gas plus 96 per cent air to 8 per cent gas plus 92 per cent air, or a range of 4 per cent.

Coal Gas—6.5 per cent gas plus 93.5 per cent air to 19.5 per cent gas plus 80.5 per cent air, or a range of 13 per cent.

Drigas—4 per cent gas plus 96 per cent air to 8 per cent gas plus 92 per cent air, or a range of 4 per cent.

Hydrogen—10 per cent gas plus 90 per cent air to 66 per cent gas plus 34 per cent air, or a range of 56 per cent (one writer says 6 per cent plus 94 per cent to 72 per cent plus 28 per cent).

Thermalene—12 per cent gas plus 88 per cent air to 30 per cent gas plus 70 per cent air, or a range of 18 per cent.

The ignition temperatures of some of the gases, at atmospheric pressure are: Acetylene, 760 to 820 deg. F.; city gas, 1100 deg. F.; hydrogen, 1075 to 1100 deg. F.

According to McCormack, the cu.ft. per pound of gases was calculated for the specific gravity and found to be: Acetylene, 14.8 cu.ft.; coal gas, 24.3 cu.ft.; hydrogen, 192.4 cu.ft.; thermalene, 13.97 cu. ft.

The Field of Gas Torch Welding and Cutting.—In a general way, the field of the gas torch welding and cutting may be outlined as follows, though some of the applications enumerated are more advantageously done by other methods. This is especially true with reference to the welding of heavy sections which should, as a rule, be done with thermit.

Airplane Construction.—Welding water jackets to cylinder, valve cages to cylinder, of manifolds (intake, exhaust, and cooling), flanges to the manifold connections, spark plug thimbles, tubular sections for frame, splice plates, sockets to frames, aluminum crank cases, water tank.

Automobile Industry.—Welding rear axle housings, defective gears and pinions, manifolds, shafts, steering posts, automobile bodies (aluminum and steel), tubing used in wind shields, etc., crank cases, transmission cases, wheels which are made of stamped-out parts, mufflers, valve stems to valves, rims, repairing crank shafts, frames, extending frame to make a truck out of a car.

Copper Plate.—Welding manifolds, flats, kettles, vats, tanks, copper, stills and chemical ware.

Electric Railway.—Welding of bonds, worn boxes, motor housings, building in teeth of defective pinions and gears, reclaiming of broken trucks, welding air receivers on air-brake system, steel trolley wires, side frames.

Forge Shop.—Welding ornamental iron, complicated parts.

Foundries.—Steel foundry: Welding up of blowholes, porous spots, blocks, cutting of risers, gates and heads; welding moldings which are cast in parts. Cast iron foundry: Reclaiming castings.

Lead Burning.—Burning of connectors on storage batteries, battery repairs, lead linings in vats, tanks, etc., lead-pipe joints.

Piping and Gas Main Work.—Welding of steam, air, gas, oil, and water lines, welding for high pressure gas distribution, ammonia systems. Fittings, such as T's, Y's, S's, crosses, which are cut and welded on the job, meter connections for houses, traps, drip pots.

Plate Welding.—Ammonia receivers, generators, air receivers, tanks for oil, vacuum driers, digesters, vats, steam driers, tanks of all kinds which are to be subjected to heat and pressure, plate assembly work for gas manufacture by-products, recovery work, stills.

Power Plant Maintenance.—Building up worn or broken parts, welding of cylinders, pistons, valve chests, etc. Welding of steam lines, of pump castings broken in service. Repairing of flywheels.

Railroad Repair.—Firebox repairs (including patches), replacing side sheets, welding in flues, cutting off rails, mud rings, welding cracked steam chest, valves, cross-heads, cylinders, building up worn pins, cutting out links, irregular shapes of steel, filling worn spots on wheels, welding spokes, cutting and welding up locomotive frames. Welding together parts of car seats, chair and window frames. Reclaiming bolsters, couplings, slotting forged engine rods; building up frogs and diamond crossings, scrappings, building steel cars.

Rolling Mill.—General repair of engines, rolls, hot beds, plates, furnace equipment, fabricating open-hearth water jacket doors, reclaiming copper tuyeres, cutting up lost heats, cutting up "kindling" or scrap, bar stock, billets, plates.

Sheet Metal.—Manufacture of metallic furniture, steel barrels, transformer cases, range boilers, kitchen utensils, light air tanks, tubing, oil storage tanks.

Shipyards.—Cutting of plates, channels, special sections, welding and reclaiming of broken parts of machinery and propellers, patching of hulls, stringers, building up of worn chocks.

Small Arms Manufacture.—Reclaiming component parts, spot hardening ot different parts, spot annealing.

Structural Steel.—Cutting as applied to coping, splicing and fitting rails, channels, I beams and other shapes. Cutting holes for rivets, welding up misdrilled holes, cutting of all kinds of gusset splice plates, cutting wrecking, welding structural parts where riveting is not possible.

CHAPTER II

THE PRODUCTION OF WELDING GASES—OXYGEN AND HYDROGEN

Oxygen is a gas which constitutes about 23 per cent by weight and 21 per cent by volume of the air we breathe, most of the other percentage being nitrogen, a gas which does not support combustion. Oxygen itself will not burn, but it is the greatest supporter of combustion known. It was probably discovered by Stephen Hales in 1727, though Priestly was the first to publish a description of it in 1774. The name "oxygen" was later applied to the gas by Lavoisier. Pure oxygen is colorless, odorless and tasteless. For welding work it is important that the oxygen used be as pure as it is commercially possible to obtain it. The impurities which decrease its efficiency are usually hydrogen and nitrogen.

There are three ways to produce oxygen commercially; by means of liquid air, by chemicals and by the electrolytic process. When oxygen is made by the liquid air process, there is a certain amount of nitrogen present. In the chemical methods, a number of impurities may cause trouble. By the electrolytic process, the impurity is hydrogen.

Oxygen by the Liquid Air Process.—As a general rule, taking everything into consideration, it is far better for the average or small user to buy his oxygen from a reliable concern and not try to manufacture it himself. The oldest concern in this country making oxygen by the liquid air process is the Linde Air Products Co., with offices in New York City. Their cylinders are regularly furnished in two sizes of 100 and 200 cu.ft. capacity respectively. They are charged to a pressure of 1800 lb. at a temperature of 70 deg. F. Customers are furnished cylinders free and pay only for the oxygen. Empty loaned cylinders are exchangeable for filled ones at stations in practically every city of fair size in the country. A 50 ft.

size of cylinder is obtainable for those whose requirements are very limited. A number of other concerns supply electrolytic oxygen for the market, the 100 cu.ft. cylinders being about 8½ in. in diameter and 48 in. high, weighing approximately 122 lb. when filled. The average purity of oxygen in cylinders is about 99 per cent.

Since the production of oxygen by the liquid air process is only applicable to large installations any detailed description of the method would be out of place here. It is sufficient to say that in general, the process consists of first reducing the air to liquid form by means of the combined action of high compression and low temperature, and then separating the oxygen and nitrogen of which it is composed, by taking advantage of the different boiling points of the two. Under atmospheric pressure the boiling point of very pure liquid oxygen is —182.7 deg. C. (—296.9 deg. F.) and of very pure nitrogen —195.5 deg. C. (—319.9 deg. F.). This means a difference in the boiling points of 12.8 deg. C., or 23 deg. F. These respective boiling points will, of course, vary under different pressures, and various degrees of purity, but the difference between the two is sufficient to allow of the nitrogen being vaporized in suitable apparatus and carried away before the oxygen vaporizes.

The Chlorate of Potash Process.—Where circumstances make the chemical production of oxygen advisable, the chlorate of potash method is probably the most satisfactory at the present time. In this process chlorate of potash ($KClO_3$) and manganese dioxide (MnO_2) are mixed together in the proportion of 100 to 13 parts (about 8 to 1). This mixture is placed in a retort filled as full as possible to exclude air. The retort is then heated and the oxygen is driven off. As the oxygen gas passes off from the retort it is conveyed through a cylinder or vessel containing sodium hydroxide (NaOH) which removes most of the impurities. The oxygen is then piped to a gasometer from which it may be used direct or pumped into cylinders. A pound of the mixture is said to produce about 4 or 4½ cu.ft. of oxygen. The manganese dioxide is unchanged during the process. It is used because it enables the chlorate of potash to more readily give up its oxygen and at a lower temperature than without it.

An oxygen generator working on the general principles just outlined is made by the Macleod Co., Cincinnati, Ohio. This firm makes both a stationary and a portable type. A stationary type is shown in Fig. 1 and a portable one in Fig. 2. The generator, which consists of a furnace with retort, a scrubber for holding the purifying solution, and a receiver

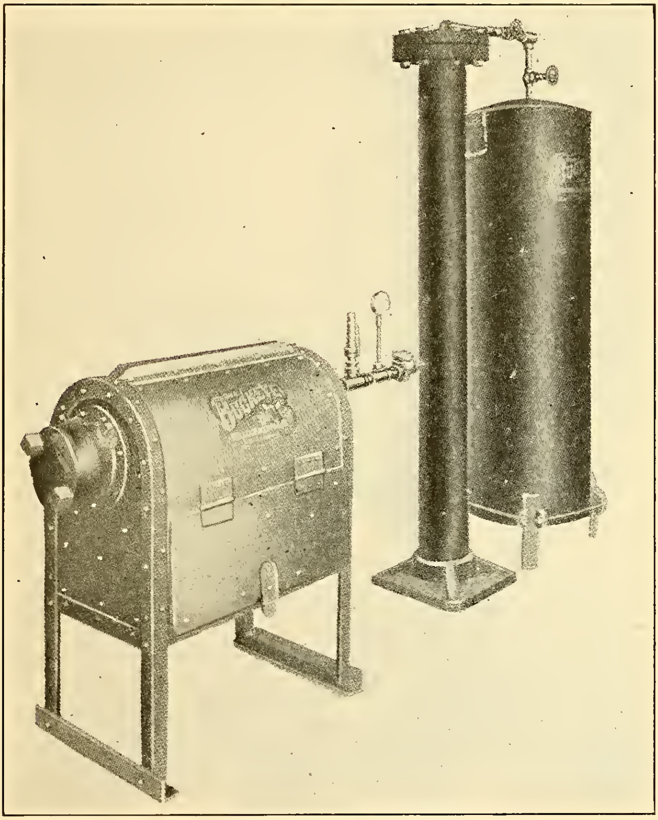


FIG. 1.—The Buckeye Chemical Oxygen Generating Set.

for the gas, is quite convenient for small shops or garages where a limited amount of oxygen is used. It is quite possible, however, to fill tanks from these generators for storage purposes and immediate use if needed. An oxygen generator may be used in conjunction with a cylinder of dissolved acetylene, or with a separate acetylene generator. Where portable generators are used for both oxygen and acetylene, it is advisable to have the outfits on separate trucks so as to decrease danger should any leaks develop.

The Buckeye generator is so made that it is adaptable to the use of wood, coal, coke or charcoal for fuel, or can be fitted with gas, gasoline, alcohol or oil burners. The portable type is shown fitted with a gasoline burner. The generators are

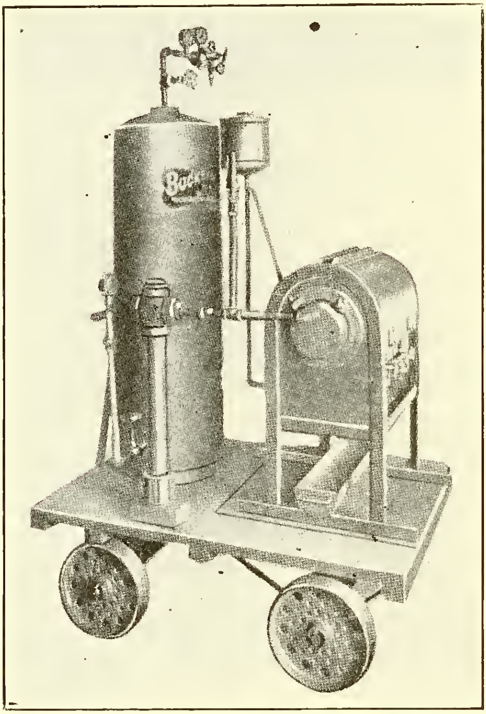


FIG. 2.—Buckeye Oxygen Generator Mounted on a Truck.

tested to $2\frac{1}{2}$ times the maximum working pressure of 300 lb. Safety devices are provided so that it is safe for practically unskilled tenders. These generators are made in three sizes, with a capacity of 40, 60 and 100 cu.ft. of oxygen per hour. The weight of the portable type will range around 650 lb. and of the larger stationary type about 1600 lb.

OXYGEN AND HYDROGEN BY THE ELECTROLYTIC METHOD

The electrolytic process for the production of oxygen is more adapted to private installations than the liquid-air process. An electrolytic installation is flexible, and may be expanded so as to produce any commercial quantity of gas desired with very little attention. One big advantage of this process is that hydrogen is produced at the same time as the oxygen, and in many cases this hydrogen can be used to advantage for welding, cutting, or other purposes.

As a rule, oxy-hydrogen for welding is less desirable than oxy-acetylene, but for some purposes, especially when there is an abundance of hydrogen available, it is very satisfactory. The heat produced by the oxy-hydrogen flame (about 2632 deg. F.) is considerably less than that of the oxy-acetylene flame (about 6300 deg. F.), consequently it is commonly employed for welding thin metals, lead burning or other work within its heat range. As a general rule, oxy-hydrogen is good for welding 16-gage steel, or thinner, but should not be used on steel over $\frac{1}{4}$ in. thick. As hydrogen contains no carbon, the weld is softer than with acetylene. Cast iron up to $\frac{3}{4}$ in. in thickness may be successfully welded, as may also aluminum crankcases or alloyed metals. For cutting, however, oxy-hydrogen has a wide field, especially for heavy work.

General Principles of the Electrolytic Method.—In an elementary form, decomposition of water may be effected by passing an electrical current between two metallic poles, or electrodes, immersed in water. By the admixture of acid or alkali, forming an electrolyte, the resistance of the water is lowered to allow a large current of electricity to pass, proportionately raising gas production. Simultaneously with the passage of current, decomposition of water into its components, oxygen and hydrogen, begins. Oxygen, exhibiting positive electrical properties, is formed on the positive pole or "anode"; double quantity of hydrogen is formed at the same time on the negative pole or "cathode." The gases are immediately available, and by interposition of a suitable diaphragm between the poles, are kept separate and led to their proper receivers.

The rapidity of decomposition, and consequently the amount of gases evolved being in direct measure of the electrical current passing, there is afforded convenient and economical means of producing commercial oxygen and hydrogen. The electrolytic solution increases in density as the action continues. The volume of water dissociated is therefore replaced at regular intervals.

Complete separation of the gases is desirable in order to insure their availability at high purity. This involves the use of a diaphragm, which, immersed in the solution, will allow passage of current between the poles and at the same time prevent mixing of gases.

The production of oxygen and hydrogen being in respect to the amount of current passing, it is apparent that the voltage required to send the specified amount of electricity through the electrolyzer is a measure of the efficiency of the apparatus, since, if the kilowatt-hour consumption is known, the gas production may be compared with it. Thus, there has been evolved the commonly accepted performance rating of any electrolyzer given in terms of cubic feet of gas produced per kilowatt-hour operation.

The production of pure gases is very important. In the earlier types of water electrolyzers the requirements for producing gases of high purity were not understood, with the result that means of purification of the gases after generation were necessary. Devices of this character have been found expensive to maintain and inefficient in action. Modern designs of electrolyzers are capable of delivering oxygen of about 99 per cent, and hydrogen of equal or greater purity, so that the need for external purifying means no longer exists.

On delivery from the electrolyzers the gases are conducted separately to a pressure regulating device which imposes equal pressures on both oxygen and hydrogen, thus equalizing the pressures on each side of the separating diaphragm. The gases are then passed to their respective gas holders, in which they are collected and stored at a few ounces pressure. Upon the nature of service of the gases will depend the size of the gas holders, and the method of compressor control.

If it is desired to compress the gases into cylinders for shipment, as in the case of a commercial plant, large gas holders are employed having capacity for, at least, a continuous day's run of the electrolyzers. High-pressure compressors draw from these holders and discharge to a manifold to which the portable cylinders are connected. The pressure carried in the cylinders is usually 1600 to 1800 lb. per sq.in. Cylinders of 100 and 200 cu.ft. capacity will weigh about 85 and 150 lb. respectively.

There are many oxy-hydrogen producing equipments installed in industrial establishments, the gases being utilized in various portions of the works. In the Davis-Bournonville installations, gas holders of moderate size are employed, their rise and fall starting and stopping the compressor motors through automatic electrical control devices.

The gases may be stored in stationary pressure tanks to a moderate amount, these being fitted with automatic regulators, so that when they are filled to capacity, the entire plant will be shut down. The gases are piped, where desired, through pressure lines, thus avoiding the replacement of empty cylinders. This method of installation is particularly desirable for continuous welding and cutting operations, either by hand or mechanical means. Provision may also be made for charging portable cylinders for use in operations carried on at isolated points.

Through the automatic control mentioned, the flexibility of an oxy-hydrogen generating and compressing equipment may be appreciated. The required amount of attendance being small, and needed only at regular intervals, continuous 24-hour operation of the equipment or intermittent service, if desired, is quite feasible and practicable. If maximum production is not desired, reducing the current passing through the electrolyzers will proportionately lower the volume of gas that is being generated.

Details of the Davis Electrolyzer Cell.—For various reasons, electrolytic installations are made up of small units or cells, which may be combined in such a way as to produce any required amount of gas. Details of an electrolyzer cell are shown in Fig. 3. This type of cell is made by the Davis-Bournonville Co., Jersey City, N. J. The type illustrated provides current conducting areas and gas generating surfaces amply proportioned to their requirements. There is sufficient over-capacity to minimize electrical resistance and afford high working efficiency. Long life of the vital parts is also insured. Research has shown that a nickel-iron-alkali combination of elements employed for electrolytic dissociation of water is a very efficient selection from an electrical input and gas producing standpoint. Parts subject to deteriorating action of any character are constructed of special material and protected by processes especially adapted to service requirements. Care has been exercised in the design so as to avoid complication of electrical and mechanical connections of small cross-section. Thus studs, bolts, busbars and their contacts are amply large for all purposes.

These electrolyzers are manufactured in two sizes, operating on specified currents of 500 and 1000 amp. respectively. The dimensions of the respective cells are 54 and 61½ in. high, 13½ and 15⅛ in. thick and 24¼ and 36 in. wide. The height given is from the bottom of the cell to the center of the highest horizontal tube, through which the hydrogen passes into the service pipe.

In stating the production of gases evolved by dissociation of water the commonly accepted formula employed specifies production of 7.93 cu.ft. of oxygen with double quantity of hydrogen per kilo-ampere-hours at normal temperature and pressure. The normal production of Davis-Bournonville electrolyzers may therefore, according to their booklet, be stated as follows:

	Normal	Hourly Gas Production	
Type	Amperage	Oxygen	Hydrogen
5	500	3.96 cu.ft.	7.92 cu.ft.
6	1000	7.92 "	15.84 "

at 20 deg. C. and 760 mm. barometer.

The closed-cell type of construction adopted eliminates the absorption of carbon dioxide (CO_2) by the solution exposed to the atmosphere in the open type of electrolyzer, and its consequent deteriorating effect upon the electrolyte and purity of gases. Electrical current passing through the electrolyzer is converted almost entirely into chemical energy for producing oxygen and hydrogen. There being practically no action on the electrolyte employed as a conducting medium between the poles other than the dissociation of water, it is evident that the electrical pressure or voltage required to send the specified amount of electrical energy through the apparatus is a measure of its efficiency.

Referring now to the illustration, it should be kept in

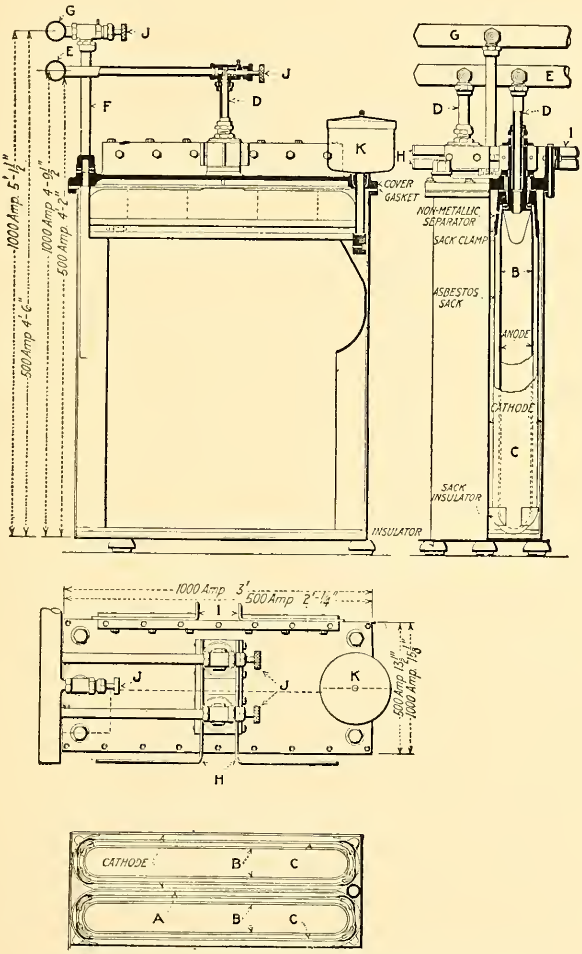


FIG. 3.—Details of the Davis Electrolyzer Cell.

mind that the solution used is water with certain chemicals, such as sodium hydroxide (caustic soda) or potassium hydroxide (caustic potash), added to increase the conductivity. The reservoir in which the solution is placed, is divided by a metal plate *A*. Anodes *B* are suspended on each side of this plate, and on these the oxygen forms. The cell itself is made of metal, and the walls of this, as well as the sides of the metal plate *A,* form the cathode or negative pole from which the hydrogen gas rises. To keep the oxygen and hydrogen separated, asbestos sacks *C* are so placed as to surround each of the two anodes. The oxygen generated passes up through the hard rubber tubes *D* connected to the pipe *E*. The hydrogen passes up tube *F* into pipe *G*. The current to the anodes is conducted through the positive busbar assembly *H*. The negative busbar assembly, shown at *I*, is attached to and forms part of the cast-iron cover of the cell and connects with the center plate and the tank walls. Valves for the three gas tubes are indicated by *J*. As the current passes through the cell the entire solution is charged and this results in the freeing of oxygen at the anodes and hydrogen at the cathodes. Since these gases have no tendency to pass off anywhere except at the respective terminals in the cell, the asbestos curtain effectively keeps them separated. The pressure of the two gases, however, must be kept the same or the one having the higher pressure will be forced through the fabric of the asbestos sacks and mix with the other gas. This is taken care of by having the gases from the pipes *E* and *G* pass through a combined flash-back and pressure regulator. The function of this device is to receive the gases; regulate their pressure through a simple water seal which equalizes the gas pressures inside the electrolyzer; separate and return to the cell any alkali carried over; provide means of replacement of water to the cell; bypass gases to the air if the delivery lines become obstructed, and to prevent admission of any flame to the electrolyzer.

The replacement of distilled water, as needed, is made through the reservoir *K*, which combines the replacement function with that of a hydraulic governor automatically adjusting the inner level of the solution. Under operating conditions, the usual replacement of distilled water amounts to approximately one gallon per 100 cu.ft. of oxygen and 200 cu.ft. of hydrogen. This replacement and the ordinary inspection usually given to the electrical apparatus is practically all the attention required for a battery of cells.

The International Oxy-Hydrogen Generator.—The electrolytic cell shown in Fig. 4 and in further detail in Fig. 5, is made by the International Oxygen Co., New York. Each cell unit requires a floor space 4 × 40 in., and with the neces-

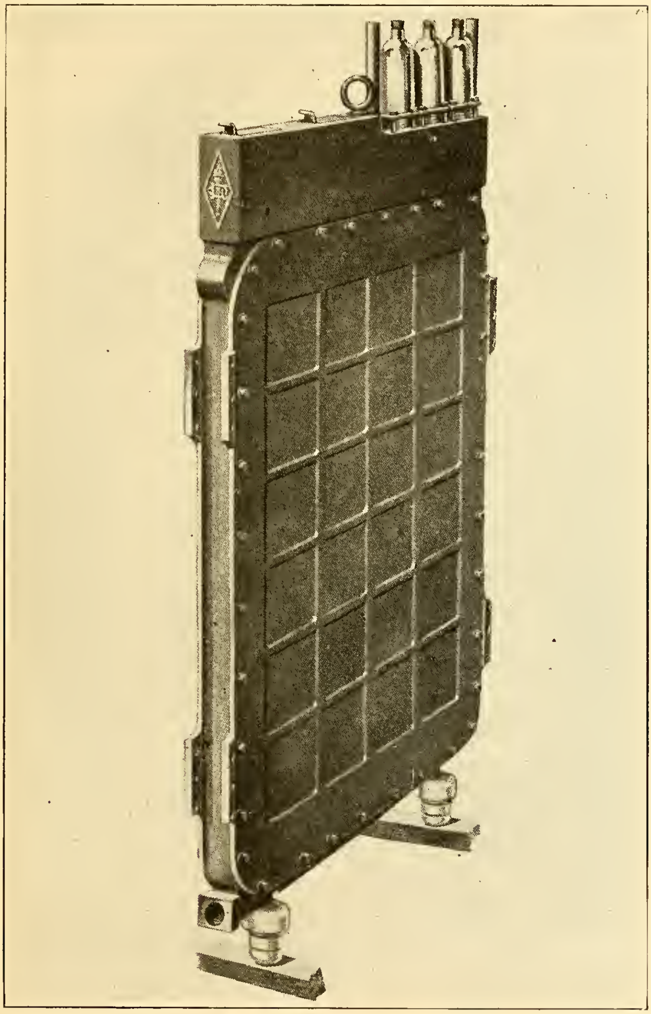


FIG. 4.—Cell Made by the International Oxygen Co.

sary pipe connections, a head room of about 6 ft. These cells are intended to be run on a normal amperage of 600 and a voltage of 2.2 each, using a caustic soda solution. The possible range above and below the normal amperage is considerable, without injury to the cells. An equipment of their type 4-1000 cells can be operated with good economy over a current range of less than 200 up to 1000 amp., representing a production range of more than one to five. In actual figures this means that an installation giving 600 cu.ft. of oxygen

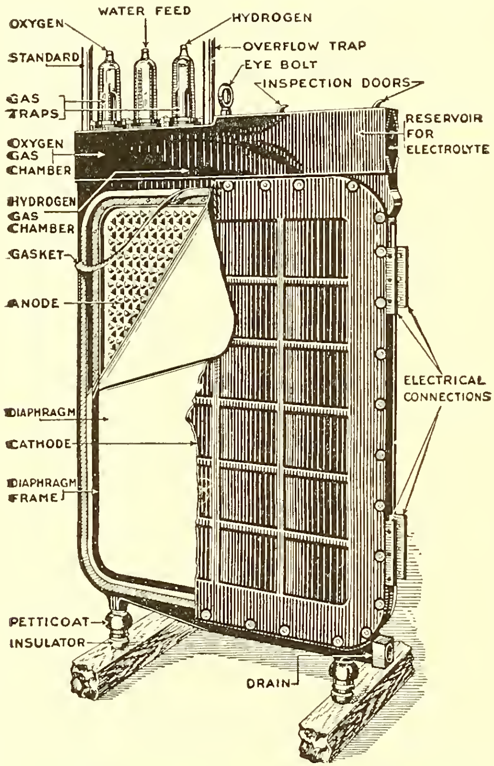


Fig. 5.—Some Details of the Cell Construction.

and 1200 cu.ft. of hydrogen per 24 hours, at 600 amp., can by varying the current and without any alteration in the plant, be made to deliver from less than 200 cu.ft. of oxygen and 400 cu.ft. of hydrogen, to more than 1000 cu.ft. of oxygen and 2000 cu.ft. of hydrogen per 24 hours. Operating at 200 amp., the power consumption per unit of gas generated is 16 per cent less than the normal 600-amp. operation. When operating at 1000 amp., the power consumption per unit of gas is 15 per cent more than at 600 amp.

Local rates will largely govern the number of cells required for a given output of the gases. Where the cost of current

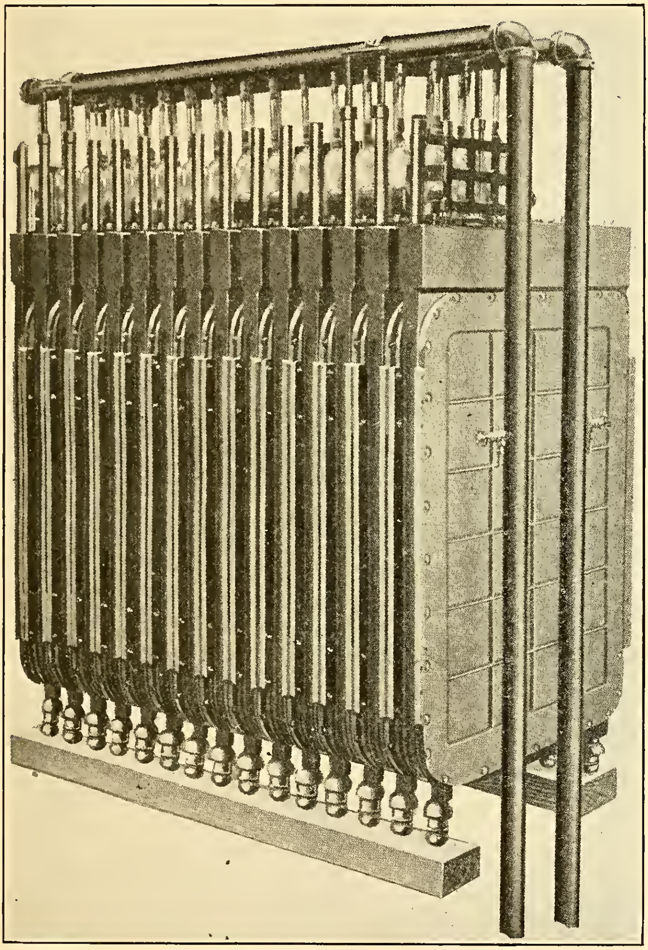


FIG. 6.—A Group of I. O. C. Cells.

is low, the plant can be economically run on current above 600 amp., the increased production per hour giving the required amount with fewer cells, since the lower current cost justifies the slightly lower electrical efficiency. Where the price of current is high, it will be advantageous to use current less than 600 amp., thus taking advantage of the higher electrical efficiency, but more cells will be needed.

In general principles, this make of cell resembles the one

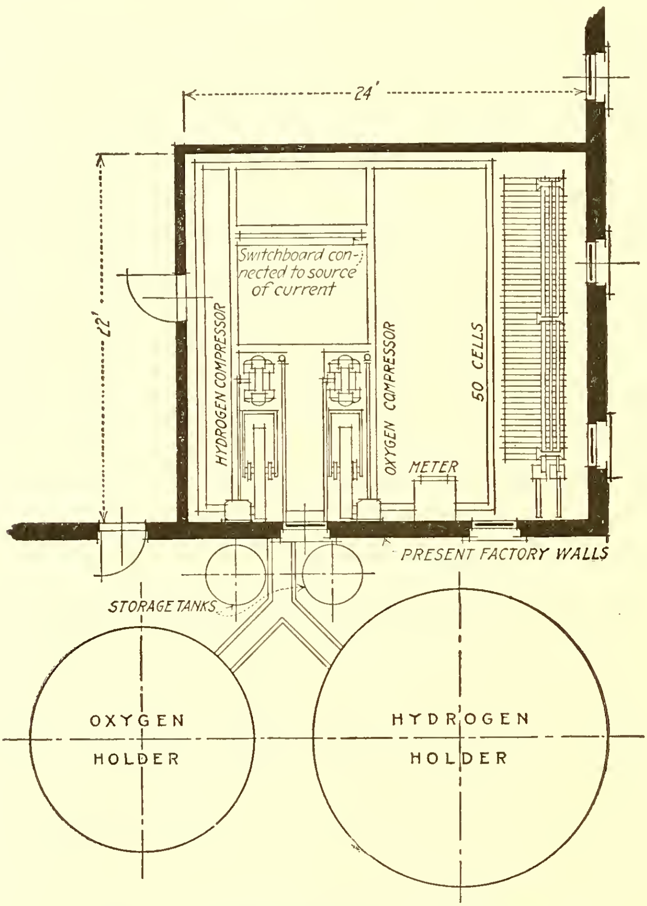


Fig. 7.—Suggested Layout of a 50-Cell Plant.

previously described, though different in form. By referring to the illustration, it will be seen that a cell is made up of a thin rectangular-shaped box frame to the sides of which are bolted two cast-iron plates or electrodes. The cavities formed between the center and side plates are divided by asbestos fabric diaphragms, forming two chambers. The asbestos diaphragms are clamped directly by metal and are not held in place by either rubber or cement. In the upper part of the

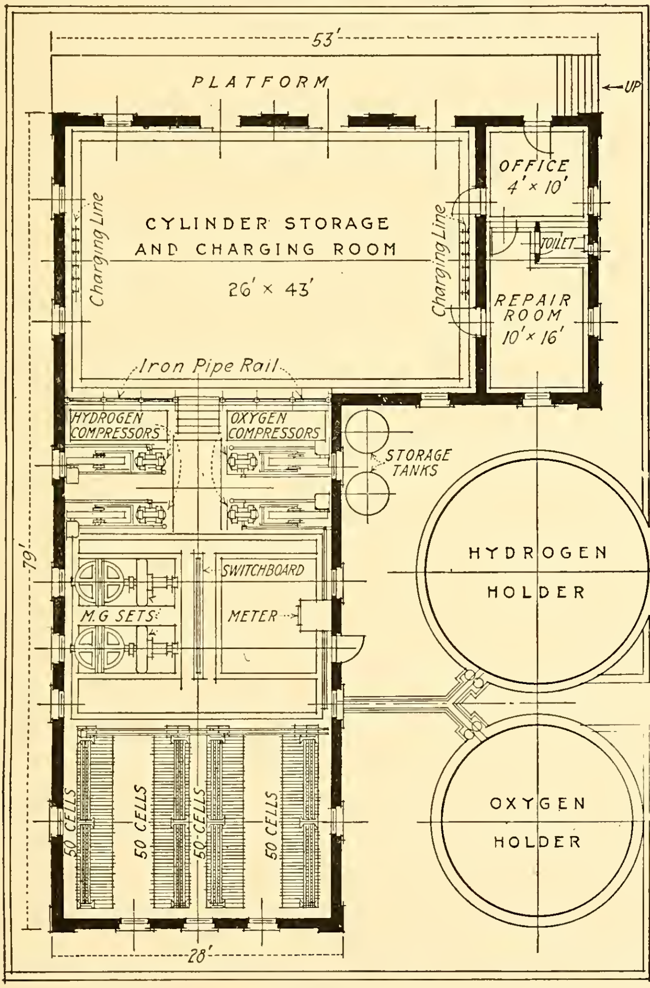


FIG. 8.—Suggested Layout of a 200-Cell Plant.

cast-iron frame are reservoirs for the electrolyte, from which it is fed to the two sides of the diaphragms. There are also two gas chambers at the top of the frame, which serve as gas traps and gas take-offs, as well as an automatic pressure-controlling device. At the bottom of the frame are communicating passages which permit the equalization of densities in the electrolyte. The cells are constructed of material which make them practically indestructible. Each cell is provided with an eye-bolt to facilitate handling. The electrodes are provided with a large number of pyramidal projections which greatly increase the area of contact with the electrolyte and facilitate the release of the gases at the generating surfaces. At 600 amp. the production of a plant per 24 hours is 105 cu.ft. of oxygen and 210 cu.ft. of hydrogen per square foot of floor space. A group of cells is shown in Fig. 6.

Two typical plant layouts are shown in Figs. 7 and 8. Fig. 7 is a layout for a 50-cell plant, with a normal capacity of 5760 cu.ft. of oxygen and twice as much hydrogen. This plant may be put in a corner of an existing building, and requires a space 22 × 24 ft. It is complete with all accessories except gas holders and storage tanks. Fig. 8 is a separate plant of 200 cells, with all necessary accessories—such a plant as might be installed for public service in cylinders for gas users. Its main dimensions are 53 × 79 ft. and it has a normal capacity of 23,040 cu.ft. of oxygen and 46,080 cu.ft. of hydrogen per 24 hours.

The Levin Type of Generator.—The generator made by the Electrolytic Oxy-Hydrogen Laboratories, Inc., Dayton, Ohio, and also of New York, is the design of I. H. Levin, after whom it is named. It is of the unit type, and is made up of a few standardized parts which can be easily assembled. Details of one of the cells are shown in Fig. 9. From this it will be seen that in the main the general construction is the same as others on the market. One noticeable difference from those described, however, is that the electrodes are made independent of the casing, being separated from and securely fixed within the casing by specially designed blocks of asbestos.

Each compartment has an independent water feed which also serves as a blow-off device to vent the gases under abnormal conditions. The surfaces of both the anode and cathode are plated with cobalt, which is said to lower the over-voltage in excess of what the gas electrodes require. The cells are sent out entirely welded, and completely and rigidly assembled, so that they may be filled with electrolyte, connected up, and put into service immediately. Each cell is $6\frac{1}{4}$ in. thick, 25 in. wide and 30 in. high, and weighs 185 lb. With the ground supports, porcelain insulators and the piping system above, the total height is 4 ft. 8 in., which brings all the parts within the range of normal reach and vision. Even

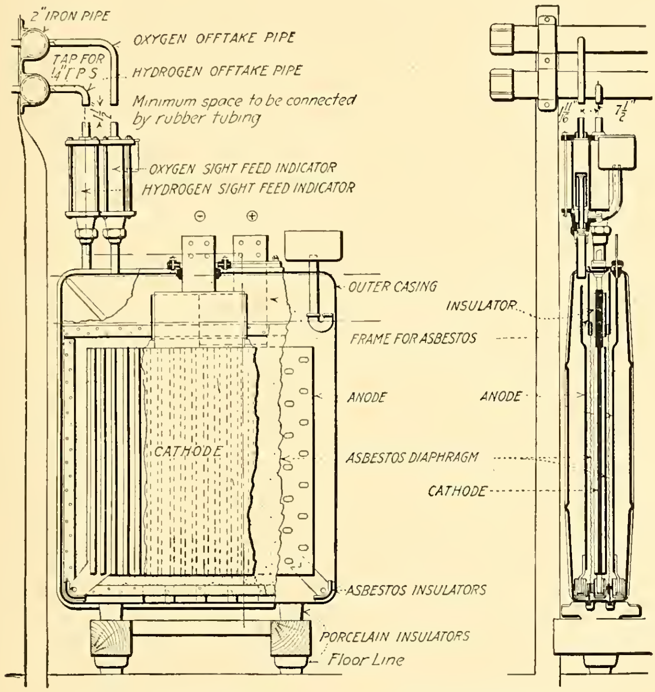


FIG. 9.—Cross-Section of the Levin Generator Cell.

a minimum aisle space of 30 in. will leave ample room for the removal or replacement of any cell. Each cell is intended to operate at a normal amperage of 250, requiring a little over $^4/_{10}$ kw. per hour. A battery of 1000 cells will occupy a space $4\frac{1}{2} \times 31$ ft. and is claimed to produce 200 cu.ft. of oxygen and 400 cu.ft. of hydrogen per hour.

CHAPTER III

ACETYLENE AND MEDIUM, OR POSITIVE, PRESSURE GENERATORS

Acetylene, which is the gas most commonly used with oxygen for gas-torch welding, is produced by the reaction between calcium carbide and water. It is used because of its large carbon content and also because of its endothermic properties, which means that it is heat absorbing and energy stored up in its formation is given off again upon dissociation. Calcium carbide and water produce acetylene and slacked lime, the formula being: $CaC_2 + 2H_2O = C_2H_2 + CaO(H_2O)$. The calcium carbide when in contact with water is divided and the carbon of the carbide joins with the hydrogen of the water to form acetylene gas. The calcium of the carbide unites with the oxygen of the water and forms slaked or hydrate of lime, as just stated.

Since calcium carbide combines with water in all of its forms it must be protected from moisture in handling. For this reason it is shipped in sealed metal drums or cans commonly holding 100 lb. From these drums the carbide is placed in generators for the purpose of liberating the gas.

Like other gases used for welding or cutting purposes, acetylene may be purchased in cylinders, but it cannot be compressed directly into ordinary steel cylinders with safety. When compressed to as much as 30 lb. per sq.in., it becomes very unstable and liable to explode unless handled with extreme care. The heat generated by compression therefore makes this a dangerous process unless means are provided for cooling. The method used in order to compress the gas and make it safe to handle is to fill the cylinders with some porous substance and then fill them with acetone. Acetone is a liquid that has the property of absorbing acetylene about the way sugar does water, and acetylene in this state is commonly known as dissolved acetylene. As acetone takes up acetylene it increases in bulk. So suppose a cylinder to be filled only with acetone and dissolved acetylene under considerable pressure. If the cylinder gas valve is opened and some of the acetylene drawn off, the acetone will shrink in volume and leave a place in the cylinder filled with undissolved acetylene gas under pressure. This free acetylene under pressure is very explosive, and easily set off from shock or heat. However, it has been found that the gas will not dissociate when finely divided, and advantage is taken of this, and the cylinder or tank is filled with porous material. For this purpose a mixture of asbestos, charcoal, kieselguhr, and a small amount of cement to hold it together, is packed into the cylinder or tank, providing a finely divided porous filling that prevents dissociation of the gas. After a cylinder has been completely filled with this mixture, slightly dampened, it is baked in an oven until the moisture is completely driven off. It is then exhausted of air and acetone is introduced into the cylinder. Acetylene is then forced into this prepared cylinder, by means of a specially cooled, multiple-stage pump, great care being exercised during the process. Each cubic foot of acetone will absorb 24 cu.ft. of acetylene for each atmosphere (15 lb.) of pressure. However, in actual practice, the quantity of acetone in a cylinder is usually so regulated that the cylinder will contain about 10 times its own volume of acetylene for each atmosphere of pressure that is on the gas. Cylinders are, as a rule, charged to 15 atmospheres pressure at 60 deg. F., so they contain 150 times their own volume when charged. Thus a cylinder that would hold 2 cu.ft. of water when empty will hold 300 cu.ft. of acetylene at 225 lb. pressure, 60 deg. F.

The filling material must be so placed in the cylinder as not to settle when handled or shipped, since if it does, a dangerous pocket will be formed filled with free gas. In handling these cylinders, it should always be kept in mind that the pressure increases as the temperature is increased. The best results are obtained by keeping the cylinders of dissolved acetylene at about 60 or 65 deg. F. An average cylinder of about 100 cu.ft. capacity will weigh about 85 lb. and one of 300 cu.ft. capacity, about 220 lb. A Davis-Bournonville cylinder, 12 × 36 in., 225 cu.ft. capacity, will weigh, fully charged, about 180 pounds.

Acetone Injurious to a Weld.—Acetone is very injurious to a weld, and in using gas from a cylinder of dissolved acetylene, care must be exercised not to use the gas too fast or acetone will be drawn off with it. The allowable rate of cylinder discharge is at the rate of one-seventh of the capacity per hour. That is, a 225-cu.ft. cylinder will supply $225 \div 7 = 32$ cu.ft. per hour. Under emergency conditions this rate may be considerably exceeded, but the practice is not economical and is liable to injure the weld.

The amount of gas in any cylinder may be found by noting the empty or tare weight stamped on the cylinder, then weighing the cylinder and multiplying the difference in pounds by $14\frac{1}{2}$. In some cases the weight marking may be different, but in any case, each pound by weight of dissolved acetylene is calculated to produce $14\frac{1}{2}$ cu.ft. of gas. To calculate the amount of acetylene used on any job, weigh the cylinder before and after and multiply the difference in pounds by the number just given. Knowing the cost of a cylinder of gas, the cost of the amount of gas used on any job may be easily found.

Weighing, which has just been outlined, is the only accurate method of computing the amount of acetylene, since gage-pressure readings are affected by changes of temperature. However, gage pressures are a great convenience in *estimating roughly* how much gas remains in a cylinder. In the case of a 100-cu.ft. cylinder, each 15 lb. of pressure represents, approximately, $6\frac{1}{2}$ cu.ft. of gas, and in a 300-cu.ft. cylinder each 15 lb. of pressure represents, approximately, 20 cu.ft. of gas.

There are three types of acetylene generators, the essential differences being the method of bringing the carbide and water into contact. These three methods are: dropping the carbide into the water; allowing the water to rise slowly into the carbide; dropping the water onto the carbide. The first is by far the most satisfactory method and the one generally used in the United States, and for this reason will be the only method described.

The carbide-to-water generators are of two types, known as positive- or medium-pressure, generators which deliver the acetylene at a pressure of more than 1 lb. and not to exceed 15 lb., and low-pressure generators which deliver gas at a pressure of less than 1 lb. While there are a number of firms making the different types, only the better known makes will be described in detail, since the general principles are the same. Modern generators of all types are automatic in their action, the feed being regulated by the flow of gas, and they are provided with an ample number of fool-proof devices which render their operation and handling safe.

The Positive-Pressure Generator.—The first positive-pressure generator built was designed by Mr. Bournonville in 1906. The present type of pressure generator handled by the Davis-Bournonville Co., is made by the Davis Acetylene Co., Elkhart, Ind. These generators are made in several sizes to meet the demands of various sized shops, and they may be had in 25, 50, 100, 200 and 300 lb. carbide capacity. These numbers indicate the weight of the charge of calcium carbide to be used, the number of gallons of water per charge, and also the number of allowable cubic feet of gas generated per hour in accordance with the rules of the National Board of Fire Underwriters.

The generators of 50 lb. and 100 lb. capacity are standard for repair shops and light manufacturing, while the larger sizes provide for more extensive and continuous use in large repair shops and metal-working industries. They are of heavy construction with powerful feeding mechanism. They are frequently installed as units to build up plants for any requirements of the oxy-acetylene process. They all have automatic feed with independent power and the quantity of carbide remaining in the hopper is constantly indicated. The acetylene gas is piped directly from the generator under the required pressure through service pipe lines to the welding stations and is regulated by means of reducing valves fitted with pressure gages to govern the proper working pressure.

The size of carbide used in the Davis stationary generators, is designated as $1\frac{1}{4} \times \frac{3}{8}$ in., and it is estimated to produce approximately $4\frac{1}{2}$ cu.ft. of acetylene gas to a pound of carbide. The size of carbide just quoted has reference to the size of screen mesh it will go through or not, that is: $1\frac{1}{4}$ by $\frac{3}{8}$ in, means that the lumps will all go through a $1\frac{1}{4}$ in. mesh screen, but none through a $\frac{3}{8}$-in. mesh; carbide quoted as $\frac{1}{4}$ by $\frac{1}{12}$ in. size, will go through a $\frac{1}{4}$-in. mesh screen, but not through a $\frac{1}{12}$-in. mesh, and so on. This smaller size is estimated to yield about 4 cu.ft. of gas per pound of carbide.

The carbide-to-water generators are designed to hold a gallon of water for each pound of carbide capacity. In practice the carbide is fed into the water only in sufficient quantity to maintain the gas supply at the required pressure. The extreme limit of safety pressure for free acetylene is 30 lb. and in the

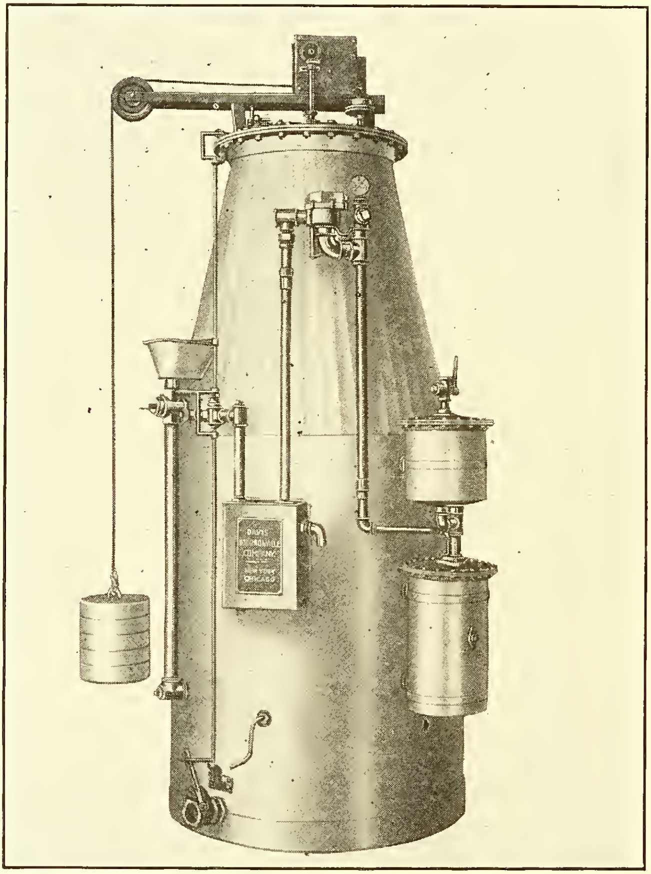


Fig. 10.—Stationary Type of Positive-Pressure Acetylene Generator.

positive-pressure types of generators the pressure limit is placed at 15 lb. When this pressure is reached, the various safety devices begin to act to prevent further generation and consequent increase in pressure. As the carbide is fed from the containing hopper it drops down into the tank of water beneath,

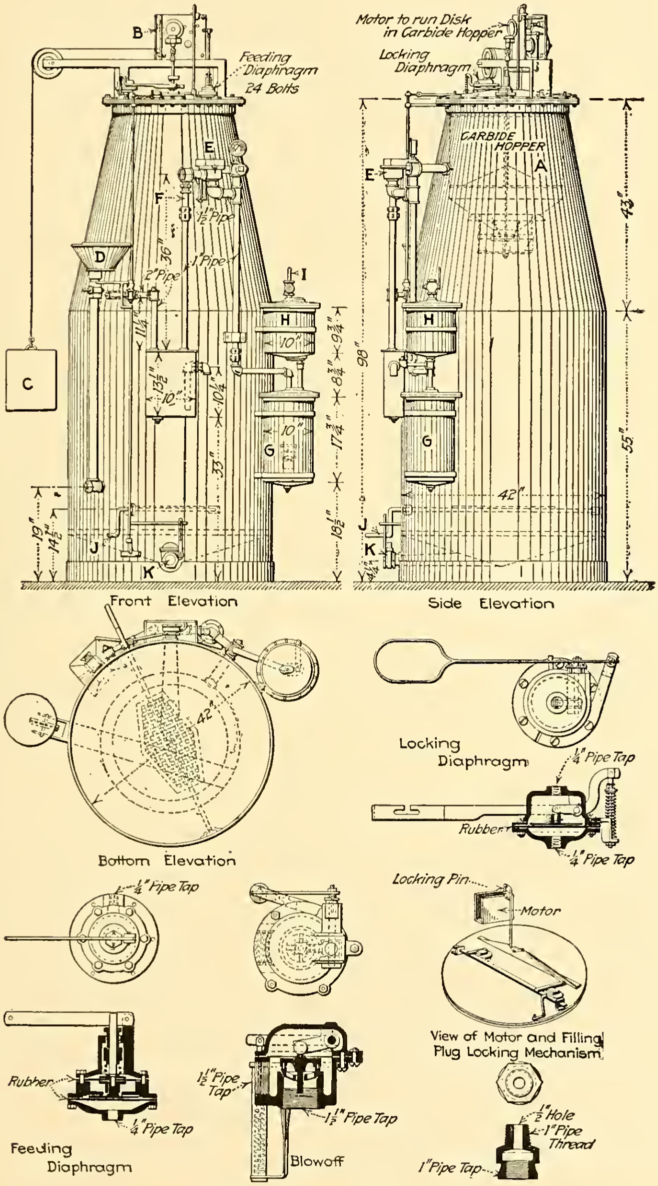


FIG. 11.—Details of 300 Lb. Carbide Capacity Acetylene Generator.

and sinks to the bottom. In this way most of the gas is generated close to the bottom of the water tank, and has to rise through a considerable body of water to reach the top. This not only serves to cool the gas but also washes out a large part of the impurities. The carbide used in these generators may be obtained from distributing points in nearly all of the large cities in the country, in sealed drums containing 100 pounds.

The acetylene generator shown in Fig. 10 is the Davis standard stationary 300 lb. carbide capacity apparatus. It is 115 in. high, 42 in. in diameter, and weighs about 1000 lb. Details of this apparatus are shown in Fig. 11. In this cut, *A* is the hopper into which the carbide is introduced from the top. A feeding mechanism at the bottom of this hopper is run by the clock motor *B*, which is operated by means of the weight *C*. The feeding device consists principally of a rotating disk with inclined vanes which sweep the lumps of carbide off into the water below. There are two safety-pressure diaphragms for stopping the motor should the gas pressure become too high. The first diaphragm acts when the pressure reaches 15 lb. If this should fail to act properly, the second diaphragm will be actuated a little above 15 lb. pressure. This last diaphragm operates a positive lock which effectually stops the motor and consequently the carbide feed. In addition to this, there is a safety valve at *E* which is connected to a pipe leading to the outside of the building, so that the gas can escape in safety. At *D* is a funnel by which water is run into the tank. As the gas is generated it is carried through the pipe *F* to the bottom of the flash-back chamber *G*. This chamber is full of water and serves the double purpose of giving the gas a second washing, and acting as a water seal between the service pipe and the gas in the generator. From this chamber the gas passes up through the filter chamber *H*, which is filled with asbestos that removes suspended impurities. From this filter the gas passes out through valve *I* into the service pipe and thence to the torches. The handle *J* operates the agitator and the tank settlings are removed through the gate valve *K*.

In addition to the regular stationary type, the Davis-Bournonville Co. makes what is called a "Navy Type." These comprise a complete equipment for use in ship-building yards, railway systems, and large industries. The installations provide acetylene

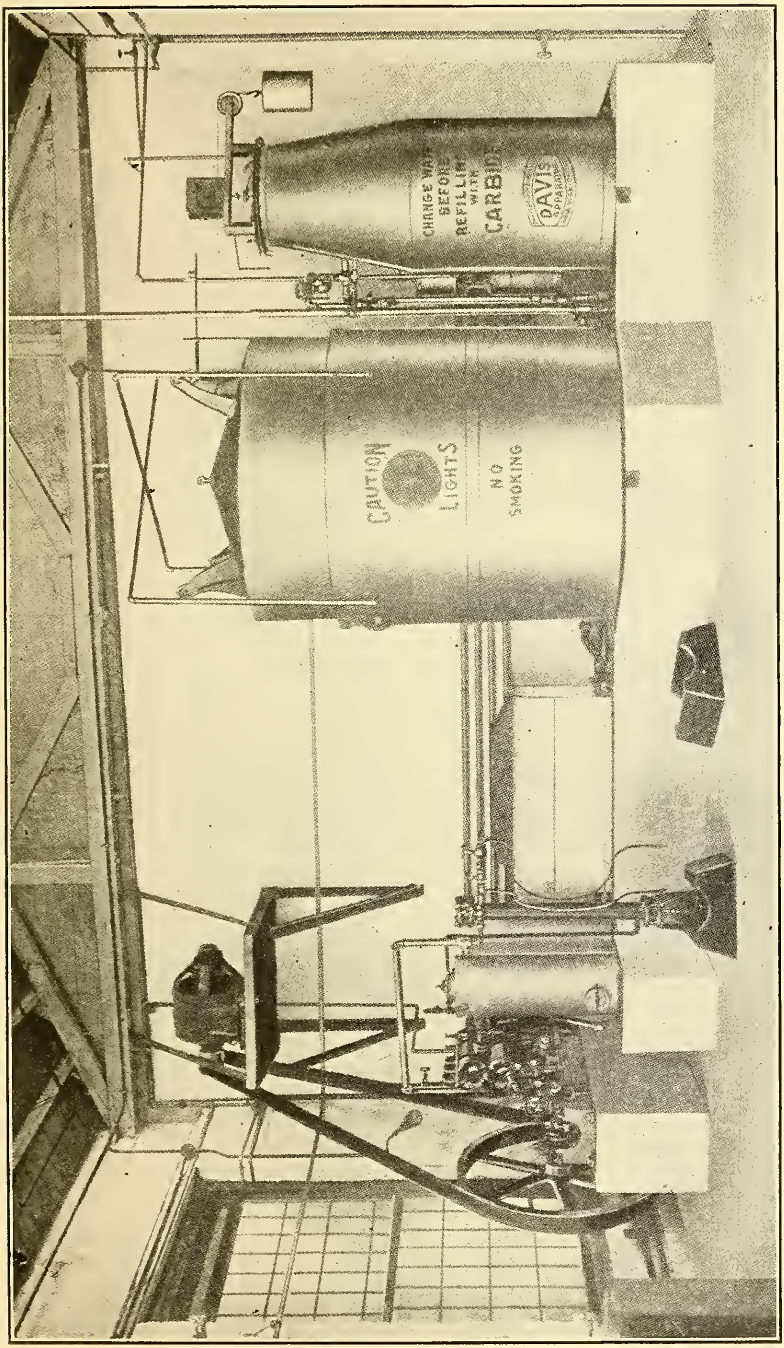


Fig. 12.—Navy Type Acetylene Generating and Compressing Installation in a Bethlehem Shipbuilding Corporation Plant.

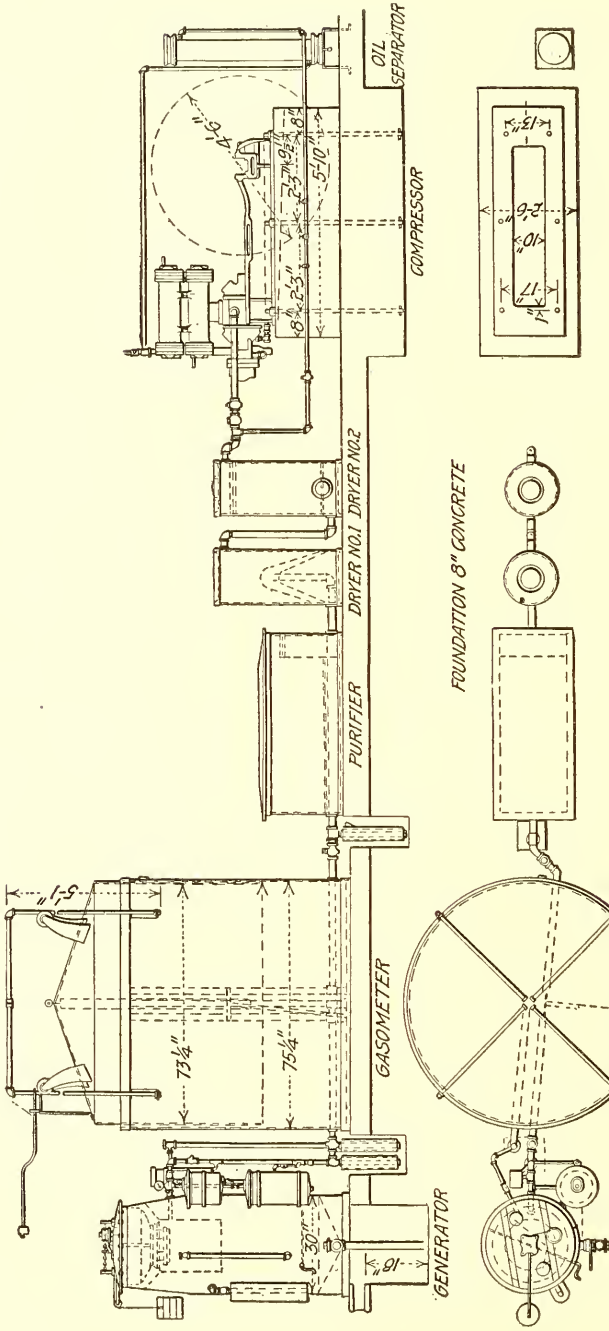


FIG. 13.—Navy Type Acetylene Plant Layout Length Over-all 36 ft. 6 in.

generation with two-pressure, air-excluding generators of large capacity, supplying acetylene under direct pressure to welding and cutting stations and an additional low-pressure supply for compression into portable safety cylinders, with purification sys-

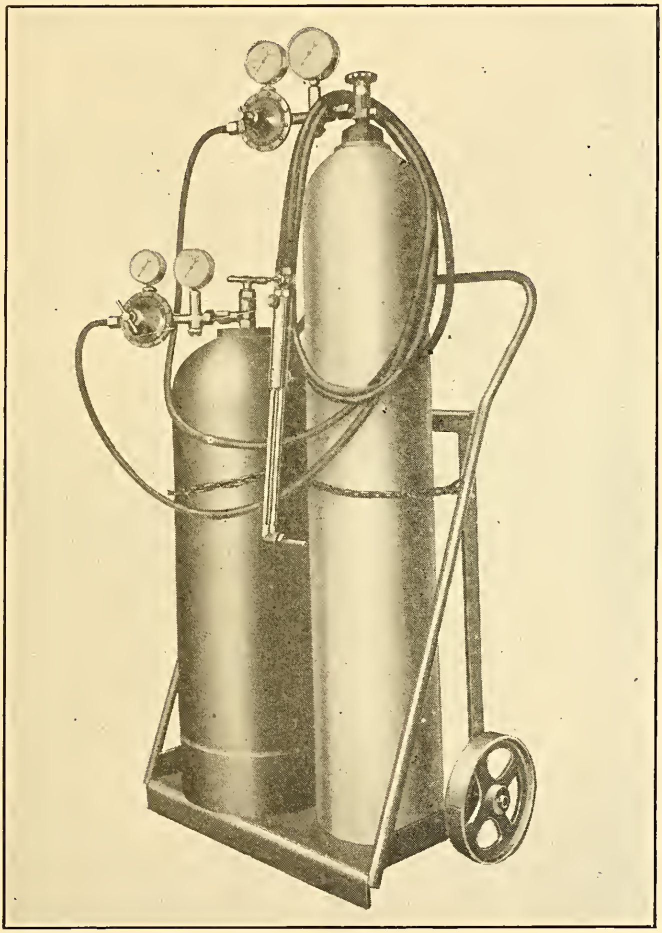


FIG. 14.—All-Steel Hand Truck for Holding Gas Cylinders and Welding Outfit.

tem, and three-stage specially designed acetylene compressor. Three sizes of the navy type, two pressure, air-excluding acetylene generators are manufactured, having a capacity of 100 lb., 200 lb., and 300 lb. of carbide each, and with normal output of

100, 200 and 300 cu.ft. of acetylene per hour respectively. When greater capacity than 300 cu.ft. of acetylene per hour is desired, two or more generators may be connected serially with a special purifying and compressing plant.

A navy type installation is shown in Fig. 12 and a suggested plant layout in Fig. 13. One of the special features of the navy installation is the low-pressure supply from which the gas is drawn for charging portable cylinders. This is done because in many places around a shipyard or other large plants, it would be practically impossible to pipe the gas or to use a portable generator. The cylinders used are, of course, previously prepared as already outlined. After charging they may be transported to the work in various ways, but for convenience they may be mounted on a small hand truck, like the one shown in Fig. 14. This truck holds an acetylene cylinder and an oxygen cylinder, together with the necessary accessories.

The approximate dimensions and weights of the various types of generators made by the Davis-Bournonville Co. are given in Table I.

The Buckeye Carbide-Feeding Mechanism.—The phantom view given in Fig. 15 illustrates the feeding mechanism used by the Macleod Co., Cincinnati, Ohio, on their pressure generators. These are made on the same principle as those just described, but this illustration gives a clearer idea of the arrangement of the feeding device. The operating motor is driven by a weight which is wound up by means of the handle on top. The way the vanes are set so as to sweep the carbide lumps into the hole in the center of the bottom of the hopper, is clearly shown.

Since commercial demands frequently make a portable type of acetylene pressure-generating apparatus desirable, such apparatus particularly suited to the requirements of large shops, ship or railroad yards and the like, is made by several firms. The Davis Acetylene Co. makes them in two sizes, of 25- and 50-lb. capacity. These generators are provided with a locking mechanism which prevents the operation of the feeding mechanism when the generator is being moved.

The Portable Pressure Type.—The portable pressure type of generator made by the Oxweld Acetylene Co., Newark, N. J., and Chicago, Ill., is shown in Fig. 16. These generators are

TABLE I.—APPROXIMATE DIMENSIONS AND WEIGHTS OF ACYTELENE GENERATOR SETS

Pressure Generator Capacity	Diameter	Height Over All	Approximate Floor Space	Net Weight	Gross Weight Crated	Dimensions Crated	Motor Weights and Fittings Crated
25 lbs.	18″	54″	4′ x 4′	200 lbs.	300 lbs.	27″x29″x 55″	10 x 10 x 14—150 lbs.
50 lbs.	24″	62″	4′ x 5′	450 lbs.	550 lbs.	34″x36″x 67″	10 x 10 x 14—150 lbs.
100 lbs.	30″	76″	5′ x 6′	550 lbs.	680 lbs.	36″x38″x 80″	10 x 10 x 14—150 lbs.
200 lbs.	37″	104″	6′ x 6′	850 lbs.	1000 lbs.	43″x48″x110″	14 x 14 x 43—400 lbs.
300 lbs.	42″	115″	6′ x 7′	1000 lbs.	1200 lbs.	53″x55″x110″	14 x 14 x 43—400 lbs.
One Torch Unit					60 lbs.	11″x12″x 23″	
Two Torch Units					90 lbs.	14″x15″x 32″	
Three Torch Units					120 lbs.	15″x21″x 32″	

NAVY TYPE PLANTS

Pressure Generator Capacity	Diameter	Height Over All	Approximate Floor Space	Net Weight	Gross Weight Crated	Dimensions Crated	Motor Weights and Fittings Crated
100 lbs.	30″	78″	5′ x 5′	550 lbs.	680 lbs.	34″x38″x 96″	14 x 14 x 43—400 lbs.
200 lbs.	36″	104″	6′ x 6′	850 lbs.	1000 lbs.	46″x48″x110″	14 x 14 x 43—400 lbs.
300 lbs.	42″	115″	6′ x 7′	1000 lbs.	1200 lbs.	53″x55″x110″	14 x 14 x 43—400 lbs.
Gasometer	75″	120″	7′ x 7′	1500 lbs.	1900 lbs.	79″x83″x 94″	(100 c. f. capacity)
Purifier		26″	26″ x 80″	500 lbs.	600 lbs.	30″x30″x 72″	
Dryers	16″	40″	16″ x 24″	80 lbs.	110 lbs.	20″x20″x 24″	(two required)
Separator	6″	52″	12″ x 12″	200 lbs.	250 lbs.	14″x14″x 72″	
Compressor		64″	30″ x 112″	2500 lbs.	2900 lbs.	36″x48″x 84″	

made with 50- and 100-lb. carbide capacity and respective productions of 50 and 100 cu.ft. of acetylene, capable of supplying 3 and 6 torches. The 50-lb. generator is 3 ft. 1 in. wide, 3 ft. 3 in. long and 5 ft. 8½ in. high. It is mounted on a 4-wheeled truck 4 ft. 5 in. wide and 7 ft. 8 in. long, with an over-all height of 6 ft. 11½ in., and a weight of 1750 lb. The 100-lb.

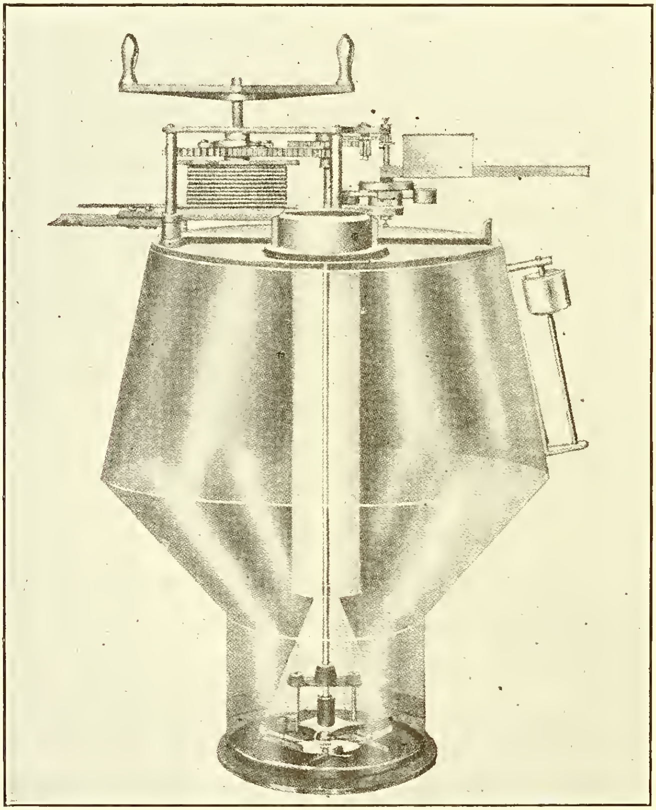


Fig. 15.—The Buckeye Carbide-Feeding Mechanism.

size is mounted on a truck 9 ft. 5 in. long, 4 ft. 10 in. wide, has an over-all height of 8 ft. 6 in., and weighs 2300 lb. This type of generator consists of a single shell which contains both the carbide hopper and the generating tank. There is no gasometer, the carbide-feeding mechanism being controlled by the pressure of the generated gas against a flexible diaphragm.

The feeding mechanism is positive in action and is provided with an automatic auxiliary no-pressure stop mechanism which closes the feed opening in case the pressure in the generator should be reduced to zero through a leak in the line or connections or by reason of any derangement in the controlling device. A locking handwheel positively locks the feed mechanism in its closed position when the generator is out of service

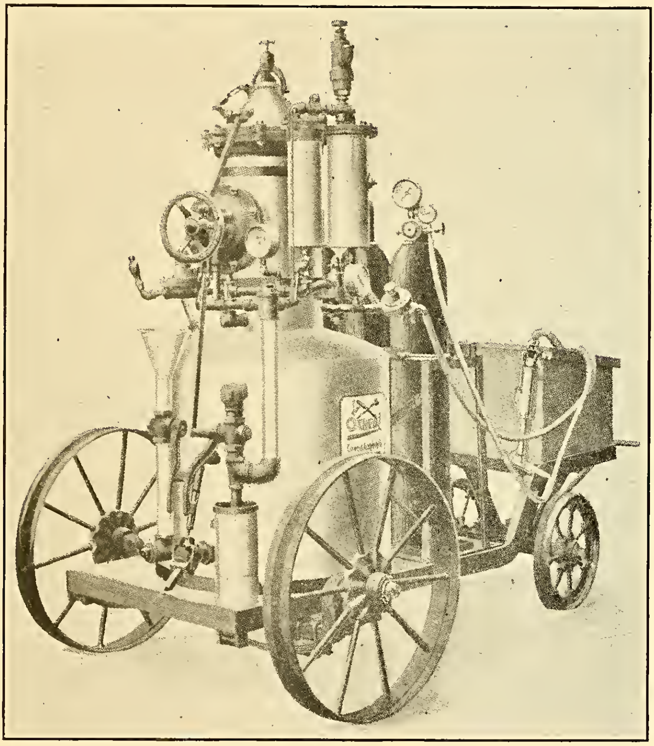


FIG. 16.—Oxweld Portable Pressure Generator.

or when it is desired to move it from place to place. This effectually prevents any carbide from falling into the water or the water from splashing onto the carbide while the generator is being moved. A complete system of interference devices connecting the filler cap, feed mechanism and residuum gate provides against mistakes in operation. The hydraulic back-pressure valve is of heavy construction and is provided with a pop valve of ample size to carry off any excess pressure. The generator is also provided with a diaphragm relief valve of special design. The filter has a cover which is interlocked with the shut-off cock to prevent the escape of gas when the lid has been removed for cleaning purposes.

The construction of the generator throughout is of a heavy and substantial character. It may be mounted on a 4-wheel truck, as shown in the engraving, or it may be located in a stationary position. Space is provided on the truck for three oxygen cylinders and a tool chest, making the entire equipment self-contained.

This same concern also makes other pressure generators in 200-, 300- and 500-lb. capacities.

Acetylene Generators	Height, Inches	Diameter, Inches	Weight, Lb.
100 lb. carbide capacity	78	30	800
200 lb. carbide capacity	104	36	1000
300 lb. carbide capacity	115	42	1200
Gasometer, 100 cu.ft. capacity	120	76	1500

	Height, Inches	Diameter, Inches	Weight, Lb.
Driers, each	40	16	80
Oil separator	52	6	200
Purifier, 24 × 36 × 74 inches	..	..	800
Compressor, 31 × 36 × 74 inches	..	..	2500

CHAPTER IV

LOW-PRESSURE ACETYLENE AND THERMALENE GENERATORS

The use of a low-pressure acetylene generator, the pressure of which is limited to 1 lb. or less, makes it possible to use a gasometer for the storage of the generated gas, with its accompanying advantage of absolute volumetric or pressure control. A phantom view of a typical low-pressure generator, made by the Oxweld Acetylene Co., is shown in Fig. 17. The carbide-feeding mechanism and tank closely resemble that of the pressure type, and with the exception of the gasometer and its mechanism, the rest of the apparatus resemble it also.

The possibility of loss of gas through ordinary leakage in the line and connections is practically eliminated with the low-pressure system. The gas bell *A* provides storage for gas and effectively guards against the loss due to after-generation. Control of the carbide-feed mechanism is accomplished through the rise and fall of the gas bell, giving a very constant gas pressure. The movement of the gas bell gives a dual motor control, first through a carefully adjusted friction brake, which provides for gradual starting and stopping, and, second, through a positive jaw clutch. Special provision is made for shutting off the motor feed when the gas bell is in its lowest position, which might result from a severe leak in the line or connections.

Operation of the generator is effected by a small but efficient weight-driven motor *B*, which is automatically started and stopped in proportion to the amount of gas being used. The motor weights *C* always lower approximately the same distance for each pound of carbide used, and constitute a reliable indication of the amount of carbide remaining in the machine at any time. The generator requires no attention whatever other than periodic recharging with carbide and water. By the use of a positive forced feed, it is impossible for more than the proper quantity of carbide to be fed to the water at a time. In order to secure cool, and hence efficient, generation, it is necessary to have not less than one gallon of water capacity per pound of carbide charge. This requirement is met by all of these generators.

A complete and efficient system of interlocking safety de-

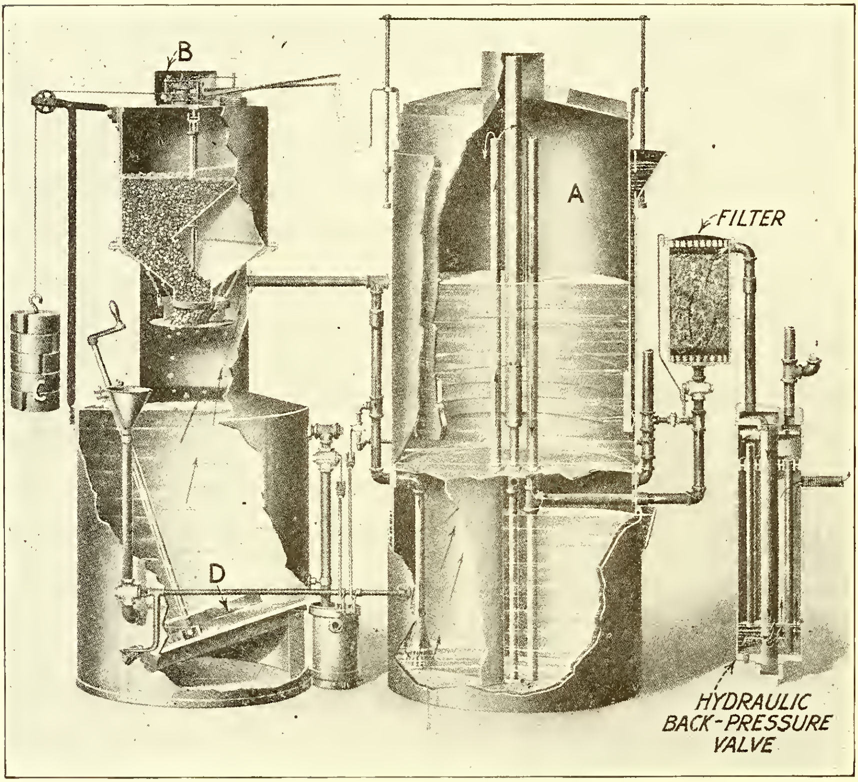


Fig. 17.—Sectional View of Oxweld Low-Pressure Generator Showing Interior Arrangement and Direction of Flow of Gas.

vices prevents mistakes in operation due to carelessness or forgetfulness when charging the generator. The hydraulic back-pressure valve with three distinct water seals prevents the possibility of any oxygen entering the generator.

The generator is equipped with an agitator *D*, which churns the residuum thoroughly, allowing it to flow out freely and quickly when the residuum outlet is opened for recharging. These low-pressure generators use the nut, or $1\frac{1}{4} \times \frac{3}{8}$-in. size carbide.

The Oxweld Duplex Generators.—The duplex form of generator, shown in Fig. 18, is designed to meet the requirements of many industries, where continuous operation of the generator, without interruption for cleaning or repairing, is essential. It is made up of two of the low-pressure generators, both deliver-

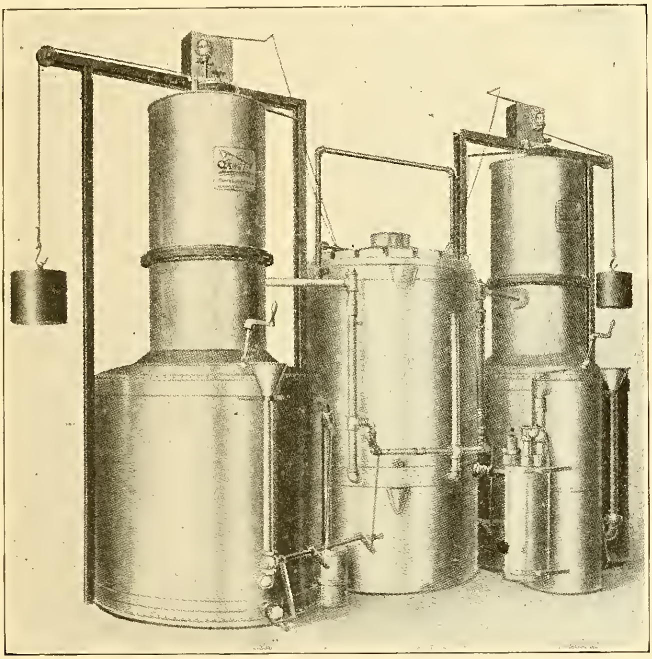


FIG. 18.—Oxweld Low-Pressure Acetylene Generator, Duplex Type.

ing to the same gasometer. Either generator can be operated independent of the other, allowing one to be used while the other is being recharged. The low-pressure generators are made in a number of sizes, details of which are given in Table II.

Reputable manufacturers always supply detailed instructions as to the care and maintenance of their generators. These should be posted in a permanent place near the generator and should be strictly adhered to in setting up, starting, and refilling.

The following general precautions should always be observed:

In charging a generator never use anything but the hands or a wooden stick to poke the carbide, on account of the danger of causing a spark.

Table II.—Oxweld Low-Pressure Generator Sizes

Carbide Capacity in Pounds	Single or Duplex	Gas Capacity Cu. Ft. Per Hour	Approx. No. of Blow-pipes	Dimensions			Approx. Shipping Weight, Complete Plant	Min. Width of Door Through Which Gen. will Pass
				Height	Length	Width		
50	Single	50	3	7′ 4″	5′ 7″	3′ 2″	1400	29½″
50	Duplex	50	3	7′ 4″	8′ 10″	3′ 2″	1800	29½″
100	Single	100	6	7′ 6″	6′ 2″	3′ 7″	1900	33″
100	Duplex	100	6	7′ 6″	9′ 8″	3′ 7″	2400	33′
200	Single	200	12	9′ 4″	8′ 0″	5′ 0″	2500	41″
200	Duplex	200	12	9′ 4″	13′ 0″	5′ 0″	3500	41″
300	Single	300	18	10′ 1″	8′ 10″	5′ 4″	4100	48″
300	Duplex	300	18	10′ 1″	14′ 1″	5′ 4″	4800	48″
500	Single	500	30	11′ 7″	11′ 3″	6′ 6″	4800	62″
500	Duplex	500	30	11′ 7″	18′ 0″	6′ 6″	6500	62″

As far as practicable do all charging, cleaning, adjusting, and manipulating of the generator by daylight.

Avoid as far as possible the introducing of air into the generator, or the circulation of air through it. Never leave any opening in the machine open longer than is necessary and never have any two openings, such as the carbide charging door and the sludge valve, open at the same time.

Keep the generator full of water at all times, even when not in use. When the sludge is drawn off and the machine flushed out, do not do anything else until it has been refilled as directed in the instructions for recharging it.

Never open the carbide filling plug, charge the machine with carbide, do any adjusting or manipulating, or make repairs, unless the generating chamber is full of water, as directed in the instructions for operating the generator.

Renew the water in the generating chamber each time any carbide is placed in the hopper. Never run more than one charge of carbide into the generating chamber without refilling with fresh water. Do not experiment.

If water in any chamber of the generator should freeze, do not attempt to thaw it with anything but hot water; and then examine the generator carefully for any damage which freezing may have caused.

If the generator should ever require repair: First, remove, all carbide; second, drain all water from the generating chamber, then refill the generating chamber as if for recharging; third, disconnect the generator from piping and remove it to the open air, then fill all the compartments with water and thus force out all mixtures of gas and air before applying soldering irons or any tools that could cause a spark. See that the workmen removing or repairing the generator understand this thoroughly.

Familiarize yourself thoroughly with the directions for operating your generator, which are furnished by its makers; and when recharging the machine follow them in the order in which they are given.

Thermalene Generators.—In composition and method of production, thermalene differs from any gas previously used for welding purposes. It is a combination produced by the decomposition of calcium carbide and hydrocarbon oil, the heat generated by the carbide being used to vaporize the oil. It is the discovery of Karl Friedrich Linus Wölf, of Zurich, Switzerland, and is handled in this country by the Thermalene Co., Chicago Heights, Ill.

Thermalene generation is a very unique proposition and was first fully described in the "American Machinist," Aug. 10, 1916. At present thermalene is principally used for welding or cutting metals, in which it is used together with the proper mixture of oxygen. The nature of the gas will be better understood by first giving a description of the method by which it is produced.

A phantom view of a generator is shown in Fig. 19. To prepare this generator for operation, water is poured in through funnel *A* until it will run out of pet-cock *B*, which fills the casing about two-thirds full. The generating mixture is carried in a tin can or cartridge that is inserted from the bottom into the cartridge chamber, as shown at *C*. Previous to inserting the cartridge, however, care is taken to pull down the cam lever *D*, which pulls up the rod and closes the water valve *E*. This prevents any water entering the cartridge chamber. After the cartridge has been inserted through the door in the bottom of the chamber, the door is closed and the bar *F* brought up and locked by means of the handwheel *G*. To generate gas the cam lever on top is pulled up as far as it will go. This admits water from the water chamber *H* into the cartridge chamber through the center tube to the bottom of the cartridge, from where it begins to work upward.

How the Cartridge Is Packed.—The cartridge is packed with

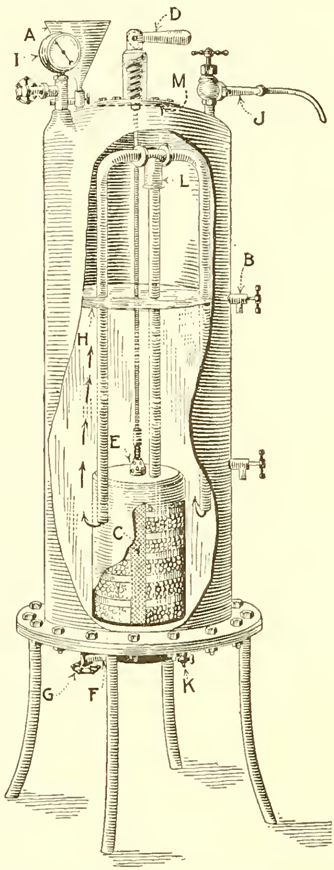


Fig. 19.—Phantom View of Thermalene Generator.

alternate layers of calcium carbide and crude oil mixed with sawdust. The water as it rises slacks the carbide and generates acetylene gas. The heat caused by the slacking of the carbide layer vaporizes the oil in the layer of mixed oil and sawdust immediately above the layer of slacking carbide and generates oil-gas. When the gas pressure as indicated by the gage is up to 5 lb., the valve *J* is opened, which lets the gas enter the hose leading to the storage tank or torch. The pet-cock at *K* is used to drain off the impurities, such as phosphor-hydrogen or ammonia, which have been separated from the carbide gas in the process of generation. At *L* is a check valve, which allows gas to escape from the cartridge chamber, but effectually prevents any return of either gas or water. As soon as a cartridge is exhausted it is easily removed, carrying all of the dirt and sludge with it.

With the use of a storage tank, enough gas is carried to run a torch while a new cartridge is being put in place in the generator, if needed. The pressure limit for welding or cutting is 15 lb. When this pressure is reached, a regulating diaphragm at *M* automatically cuts off the water feed and stops the generation of gas. This diaphragm is placed at the top of the generator, on the inside, where the gas pressure acts directly on it. The diaphragm is connected to the feed-valve rod in the center, so that as the diaphragm is forced upward by the gas pressure, the water valve is partly or wholly closed. It is so arranged as to be easily set for various desired pressures.

As previously stated, the cartridges are made up of alternate layers of calcium carbide and oil-soaked sawdust. Now it is well known that the volume of lime into which calcium carbide is converted by the slacking process is greater than the volume of the carbide. Therefore, when carbide is packed tightly in cartridges, as desirable, the expansion is liable to burst the case, and in some instances might cause the cartridge to jam in the chamber, as well as interfere with the successful working. One of the objects then is to so make the cartridge as to allow for the expansion of the contents. Another is to prevent the oil from coming in contact with the carbide, as this would interfere with the action and decrease the gas output. To summarize, the cartridge components must be so arranged as to promote free action of the carbide; free action of the heat evolved from the carbide on the volatile substance; to prevent action of moisture on the carbide layers not being acted upon purposely; and to promote the free discharge of the generated and volatilized gases.

All of these points, as well as a number of others, have been considered in the makeup of the cartridges, as shown in detail in Fig. 20. As made at present for commercial purposes, there are four sizes corresponding to the different outfits. The cartridges consist of a tin can of suitable size, the smallest being $4\frac{3}{8}$ in. in diameter and 8 in. high, weighing 6 lb. and having a gas-producing capacity of 25 cu.ft., sufficient to supply a welding torch from four to five hours. The largest size is $9\frac{3}{4}$ in. in diameter and 16 in. high, weighing 40 lb. This has

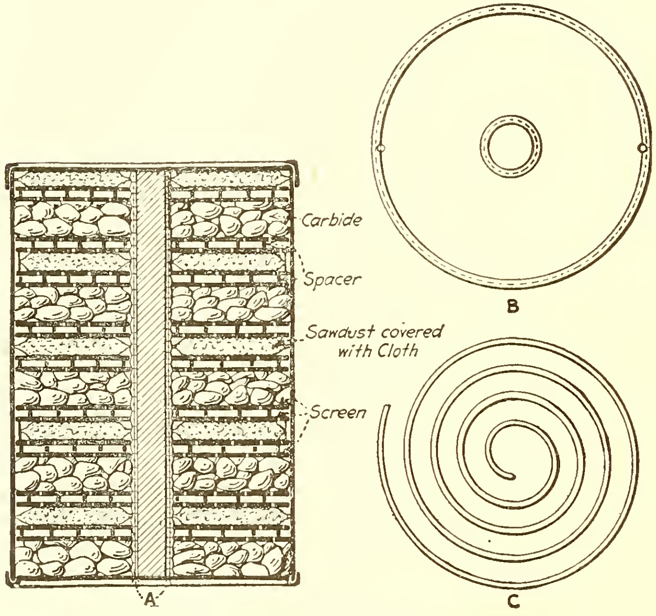


FIG. 20.—Details of Thermalene Cartridge.

a gas production of 200 cu.ft., or eight times the capacity of the smallest size which has been previously mentioned.

Referring now to the illustration, a cylindrical screen *A* is first placed in the can to be filled and then a layer of carbide is placed in the bottom of the can around the screen tube. An unglazed carboard disk *B* is next placed on top of the carbide. A spacer *C*, made of thin metal bent so as to lie edgewise, is placed on top of the cardboard and then a disk of screen is put over it. Sawdust impregnated with crude oil in a cloth sack made of two cloth disks sewed together is laid on the screen.

On this is another screen, then a spacer and a cardboard disk, and so on to the top, ending with a sack of oil, soaked sawdust covered with a piece of screen that has no hole in the center for the cylindrical tube. The end of the can is closed with a cover for handling, which is removed before placing in a generator.

As previously mentioned, the water feeding in through the valve in the cartridge chamber drips down through the cylindrical screen tube and starts slacking of the lower layer of carbide, the heat of which vaporizes the oil in the sack above it. The cardboard disks, while strong enough to hold the layers firmly in place while dry, begin to soak up as soon as the feeding starts, and consequently become soft, so as to give way under the pressure of the expanding carbide, allowing it to be forced into the spacing between the carbide and the oily sawdust. This space is so calculated as to keep the various layers firmly in place until the cartridge is exhausted. Another thing is that, as any liberated steam or water vapor must pass through the absorbent cardboard as well as the oil, before it reaches the next layer of carbide, action of the steam on the carbide above is prevented. This insures that the respective layers of carbide will not be acted upon until the water becomes level with them in turn. In consequence, a cartridge can remain in a generator a long time without becoming spent. The screen disks on top and bottom of each layer of oily sawdust furnish efficient volatilization and egress for the gas.

By the method of producing thermalene, the heat evolved by the generation of acetylene is absorbed, at the place of generation, in the production of the oil gas. This utilization of heat serves to keep the temperature down, since the heat generated is used and dissipated by the latent heat of the oil, so that radiation and absorption by water is not necessarily depended upon. The gas combination that results passes out through the T-pipe ends and bubbles up through the water into the upper part of the generator. The low temperature causes the impurities to drain back into the chamber, from which they are easily removed. The layers of carbide and oily sawdust are so proportioned as to cause only the vaporization of the lighter oils, such as benzine, naphthalene, kerosene and the like. The temperature is not high enough to vaporize the tar oils, as these are heavy and give a deposit of lampblack. These heavy oils are therefore not utilized, but remain in the cartridge. The temperature in the cartridge is maintained between 200 and 300 deg. C. (392 to 572 deg. F.), depending upon the rapidity with which the gas is being used and the amount which is generated and delivered. It is not intended that an actual boiling take place at any time, for if the temperature is too high there will be a vaporization of the heavy oils, causing deposits in the pipes and also an increase in the impurities. The gases passing through the pipes cooled by the water of the generator are kept between 60 and 70 deg. F. In the passage through the cooled pipes the impurities are removed in the following manner: Acetylene has a comparatively high specific heat, so that its rate of cooling when passing through the pipes is low. The specific heat of oil gas is, however, only one-eighth of that of acetylene, so that its cooling effect will be eight times as great. Now if the two gases are passed together along a cooling surface, the temperature of low specific heat will decrease rapidly and cause a rapid lowering of the temperature of the other gas. This causes a deposit of the vapors suspended therein. So this action results in the deposit of the sulphur, phosphorus and silicon compounds, and of the ammonia. In order, however to bring about this precipitation the temperature must be sufficiently low—that is, as stated above, between 60 and 70 deg. F. If the gas finally issuing from the pipes and water was too hot, the impurities would not be thrown out.

In this process the acetylene and oil gas, generated and cooled, will combine in the pipes after the impurities are removed. It is important, however, that the impurities be removed and the product sufficiently cooled, since no real combination will take place at too high a temperature. For instance, if the water is above 180 deg. F. the oil burns and no proper combination results.

The combined gas produced, named thermalene, possesses marked characteristics that distinguish it from oil-gas, from acetylene, and from the usual mixture of the two. The density is greater than air, being 1.1 taking air as unity. The issuing gas can be seen to sink when thrown through a sunbeam. The specific heat is low, being a little over one-eighth of that of acetylene. Thermalene liquefies at between 1400- and 1500-lb.

pressure per square inch at room temperature, and in its liquid state is nonexplosive and stable. A very noticeable thing is the odor, which is not at all like the odor of either acetylene or of oil-gas, but is a soft, sweet smell, not strong or offensive in any way. The color is white, but with a predominating proportion of the red and yellow parts of the spectrum. The

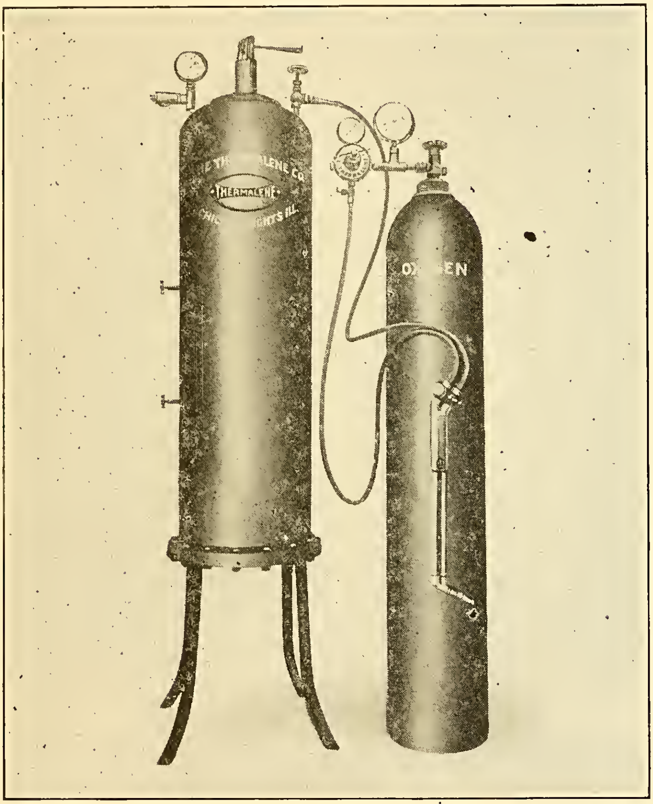


FIG. 21.—Thermalene Outfit for Shop Use.

maximum flame temperature, according to H. McCormack, professor of chemical engineering, Armour Institute of Technology, Chicago, Ill., has been found to be about 6500 deg. F. The high density of the gas has a number of advantages. It has more body than acetylene and does not need so much oxygen. Moreover, it mixes better with oxygen. It does not explode as readily as acetylene, so can be mixed with greater proportions of air. In a Bunsen burner it is possible to mix as much as 32 per cent of air without causing a flareback. It can readily be turned down without causing a flareback, and it can be used with a Welsbach mantle to advantage. The upper and lower explosive limits are 12 per cent and 30 per cent. It averages approximately 13.97 cu.ft. per pound.

Some Advantages of Thermalene.—When used for welding and cutting, thermalene has numerous good points. It does not

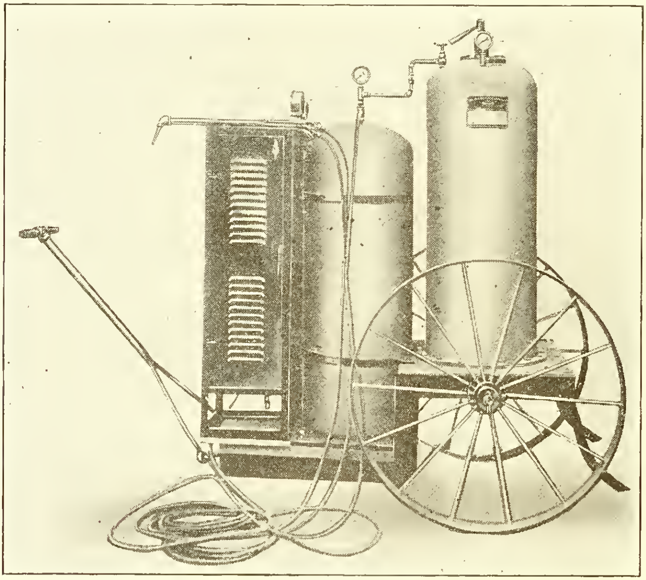


Fig. 22.—Portable Thermalene Generator Outfit.

require an excess of oxygen, and the flame, therefore, produces a soft weld, especially in cast iron. When welding it is noticeable that less sparks are thrown off than when using acetylene. It can be used at a lower pressure also, owing to its greater calorific value. Owing to the removal of the various impurities, there are no corrosive effects on fittings, nor poisonous effects. It is also for this reason that there is little or no danger of explosion. Neither does the spent cartridge give off explosive gases, for the reason that the gases liable to cause explosion are separated and drained off from the generator chamber. Corrosion of interior walls, due to water action, is prevented by the oil vapor which is always present and forms a protecting and sealing effect throughout.

A thermalene generator may discharge its gas into a storage tank, or the gas may be used direct from generator to torch. A welding or cutting outfit, suitable for shop use, where it will not need to be moved frequently, is shown in Fig. 21. Here the gas is used direct from generator to torch. The smallest generator like the one shown is $10\frac{1}{8}$ in. in diameter, stands 3 ft. 9 in. high, and weighs about 60 lb. An apparatus mounted on a truck is shown in Fig. 22. As a rule a No. 2 generator is used for this purpose. This size is 16 in. in diameter, stands 6 ft. high, and will produce 70 cu.ft. of gas with one charge, the generator weighing 225 lb. and the storage tank 120 lb. The largest size generators will produce 200 cu.ft. of gas per charge, and they may be coupled in batteries where a large amount of gas is desired. These can be arranged so that part of them can be recharged while the others are working, or storage tanks of sufficient capacity may be used to allow for recharging.

CHAPTER V

GAS TORCHES USED FOR WELDING

The gas torches used for welding in the United States may be divided into two general types, known as medium-pressure and low-pressure torches. Each type is made in a number of sizes, and each size is usually provided with a number of interchangeable tips for producing flames of different size.

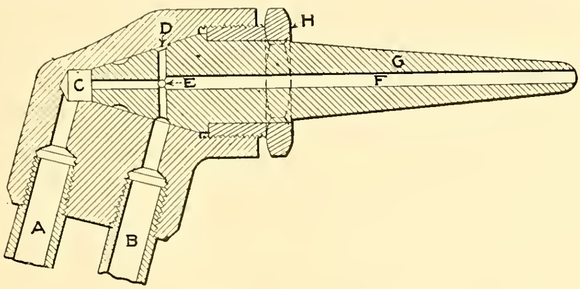
The medium pressure torches are also known as positive-pressure torches, and to avoid misunderstanding, they will be referred to as positive-pressure torches hereafter. In these torches, using acetylene and oxygen for welding, the acetylene pressure will range from 1 to 14 lb. and the oxygen pressure from 1 to 24 lb. per square inch, the pressure employed depending on the thickness of the metal being welded, the make of torch, and the tips used. The pressures given may even be exceeded in some exceptional cases.

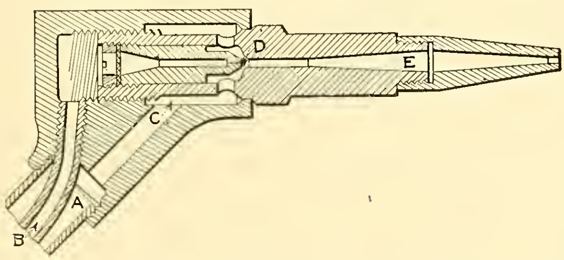
A sectional view of a typical positive-pressure welding head is shown in Fig. 23. The oxygen enters at *A* and the acetylene enters at *B*. The oxygen goes to the small chamber *C* and thence out through the center hole. The acetylene goes to the chamber *D* and also out through the center hole, the two gases starting to mix at the point *E*, and as they pass out through the channel *F* to the end of the tip, they are thoroughly mixed. In this illustration, the removable tip is indicated by *G*. This make of tip has a conical seat and held in its place by means of the lock collar *H*. Made in this way, there are no threads on the tip itself, although the practice varies in different makes.

The low-pressure torch is also known as the injector type. In this type of torch, the acetylene, or other gas, is supplied under a pressure of a few ounces up to 1 lb., but the oxygen may have a pressure of from 5 to 30 lb. per square inch, according to the size of tip being used. In some cases the oxygen pressure may be either higher or lower than the figures given.

A sectional view of a typical low-pressure torch is shown in Fig. 24. In this torch the acetylene, or other gas, enters at *A* and the oxygen at *B*. The acetylene goes to the chamber *C* from which it is sucked by the oxygen pouring out through the nozzle at *D*, and it is carried along with the oxygen into the mixing chamber *E* in the tip of the torch. From this chamber the gases issue thoroughly mixed and ready for combustion.

As they qualify for classification as either positive-pressure





FIGS. 23 and 24.—A Typical Positive-Pressure Welding Torch and a Low-Pressure or Injector Type of Welding Torch.

or low-pressure types of torches, the various makes of each type differ principally in form, the general principles of action remaining the same. A few examples of the different makes of positive-pressure torches will be shown first, and these will be followed by others of the low-pressure or injector type.

A standard form of a positive-pressure welding torch, made by the Davis-Bournonville Co., is shown in Fig. 25 and in detail in Fig. 26. A number of torches used for various purposes are shown in Fig. 27. In this illustration, *A* is a small lead-burning torch. *B* is a midget torch used for welding very light sheet metal for manufacturing purposes, such as the seams of cooking utensils, aluminum ware, etc. It weighs about 8 oz., is 10 in. long, and may be used on sheets up to $\frac{1}{8}$ in. thick. *C* is a small-size torch for metal from $^1/_{32}$ to $^5/_{16}$ in. thick, weighs 18 oz., is 14 in. long and uses oxygen pressures, with different tips, of

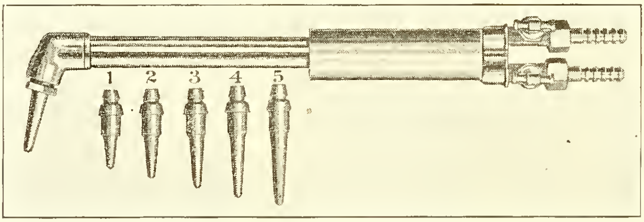


FIG. 25.—The Davis-Bournonville Style C Positive-Pressure Welding Torch.

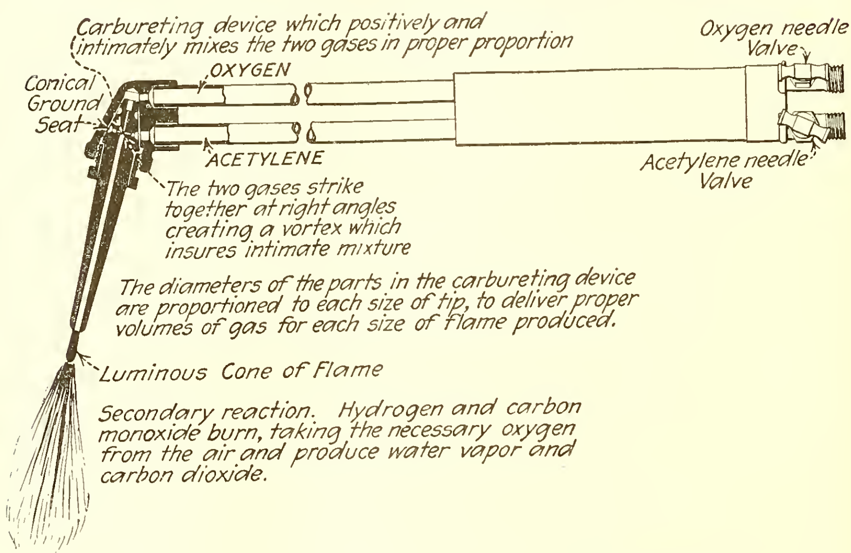


FIG. 26.—Details of the Davis-Bournonville Welding Torch.

from 2 to 10 lb. *D* is a manufacturer's torch, intended for use on boilers, steel barrels, metallic caskets, tanks, cylinders, etc. The head is set at right angles to the body, which has been found best for this work. It weighs 24 oz., is 18 in. long and uses oxygen at 2 to 10 lb. pressure, according to the tips employed. *E* is a large torch for heavy welding. It weighs 2 lb., is 20 in. long, and uses oxygen at 12 to 20 lb. pressure. It is used on metal from $\frac{1}{4}$ in. thick up. *F* is a water-cooled torch, used for heavy welding where the tips have a tendency to become overheated. It is 36 in. long and weighs about $3\frac{1}{2}$ lb. Four lines of hose are needed with it, two for water and two

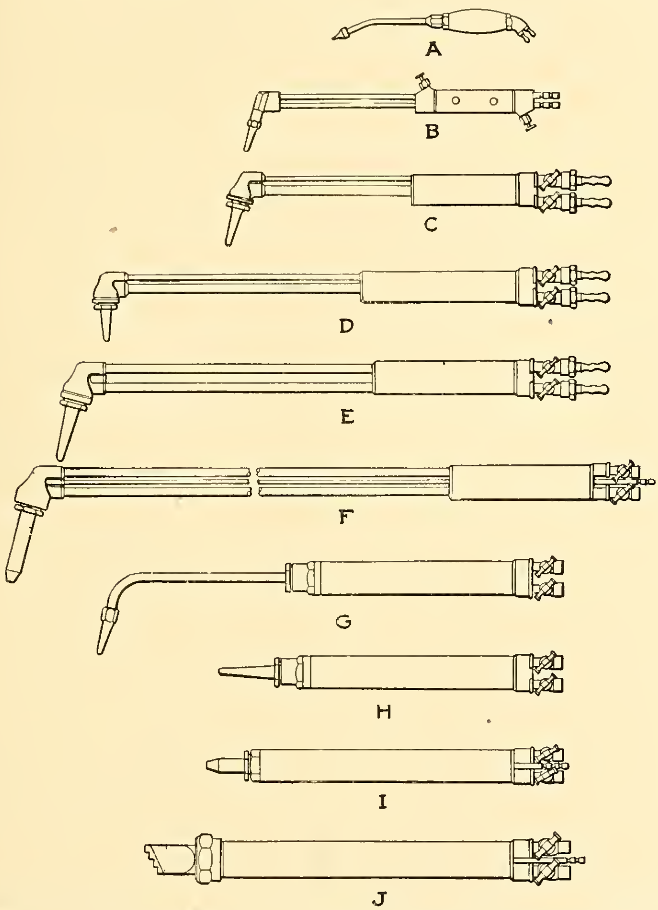


Fig. 27.—Various Models of Davis-Bournonville Welding Torches.

for gas. *G* is used for welding with oxygen and hydrogen. *H* is for use on a welding machine. *I* is a water-cooled torch for a welding machine. *J* is water-cooled, for machine use and has a multiple-jet nozzle or tip. All of the torches mentioned are furnished with five interchangeable tips for different thicknesses of metal. These tips, however, do not fit torches of different size; that is, the tips for large torches will not fit small ones, nor vice versa. All the torches named are intended for oxygen and acetylene, except where mentioned otherwise. A number of different tips designed to be used with the torches illustrated, are shown in Fig. 28.

The approximate pressures of oxygen and acetylene as used in the Davis torches are given in Table III. The tips referred to in compiling this table are known as styles Nos. 99 and 100,

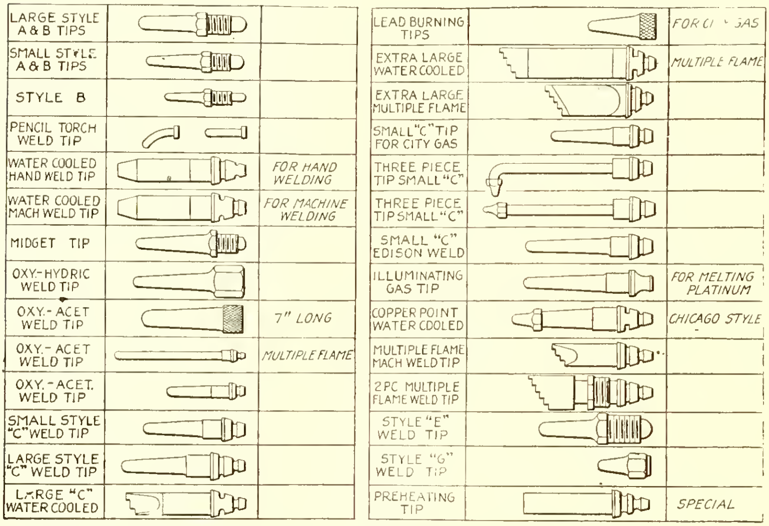


FIG. 28.—Different Kinds of Tips Used with Davis-Bournonville Welding Torches.

and are used with style *C* torches. These pressures serve only as approximate guides and are not to be taken literally in practice.

The Prest-O-Lite Torch.—The torch shown in detail in Fig. 29 is made by the Prest-O-Lite Co., Indianapolis, Ind., but is handled by the Oxweld Acetylene Co. This torch is fitted with a long stem through which the gases pass and are thoroughly mixed before issuing from the nozzle.

The stem is fitted to the mixing chamber by means of a union nut, which permits the operator to point the welding tip in any direction, without changing his method of holding the torch. This is particularly advantageous for vertical and overhead welding. Both oxygen and acetylene inlets on the torch are fitted with fine-adjustment control valves. The one on the oxygen supply is so placed that the operator while working can make any slight necessary adjustment with the forefinger of the hand that grips the torch. The handle of the torch is fitted with anti-fireback chambers for both gases, filled with a special material through which it is impossible for a flame to pass.

TABLE III.—APPROXIMATE GAS PRESSURES FOR DAVIS-BOURNONVILLE STYLE C WELDING TORCH, WITH NOS. 99 AND 100 TIPS

Tip No.	Thickness of Metal Inches	Acetylene Pressure Lbs.	Oxygen Pressure Lbs.
00	Very Light	1	1
0		1	2
1	1/32–1/16	1	2
2	1/16–3/32	2	4
3	3/32–1/8	3	6
4	1/8–3/16	4	8
5	1/4–5/16	5	10
6	5/16–3/8	6	12
7	7/16–1/2	6	14
8	1/2–5/8	6	16
9	5/8–3/4	6	18
10	3/4–Up	6	20
11	Extra Heavy	8	22
12		8	24

The torch is easy to dismantle, as all parts are screwed together on metal-to-metal seats and no packing or solder is used at any joint.

For extra heavy work, a special stem 22 in. long is furnished, and for close work a 5½-in. stem may be had in addition to the regular size. The regular stem has seven tips, the largest four being of copper which will stand up against the intense heat radiated from the work better than any other metal. The smaller tips are of a special alloy. A similar torch is also made for very light work which weighs only 3 oz. complete.

In the detailed view given of the torch, *A* is the hose nipple through which the oxygen passes. At *B* is a set of 40 strainer cloths for the oxygen filter chamber; *C* is the oxygen needle valve; *D* is the acetylene hose nipple; *E* is the acetylene

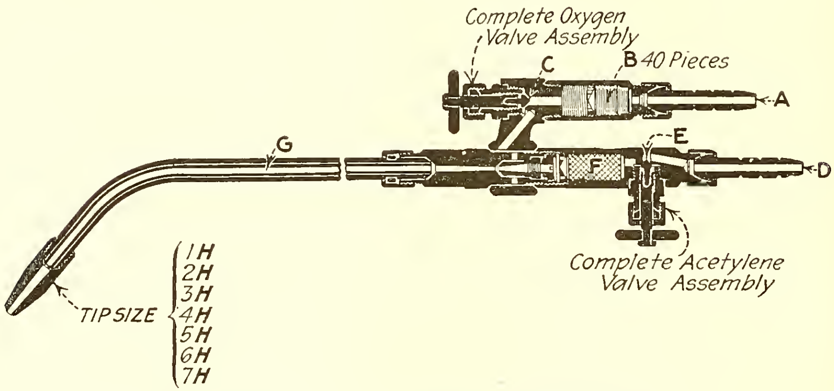


Fig. 29.—Details of Presto-O-Lite Type H Welding Torch.

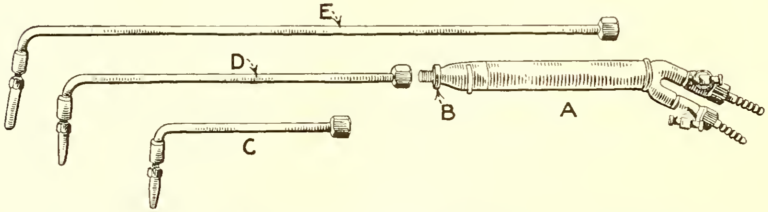


Fig. 30.—Torches Made by the General Welding & Equipment Co.

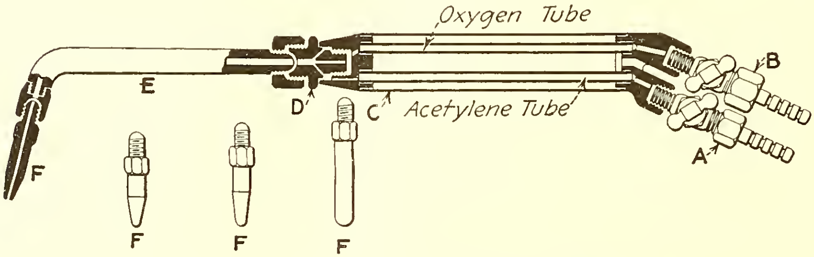


Fig. 31.—Details of Torch Shown in Fig. 30.

needle valve; *F* is the acetylene filter-chamber cartridge; *G* is the stem. The seven tips are indicated from 1*H* to 7*H*, and their openings can be determined from Table IV. This table is especially valuable in that the nozzle openings are shown in regular twist-drill sizes, furnishing an easy method of comparison. The two tips given at the bottom of the table are extras, used for heavy work. The figures quoted in the table are based on straight work on steel plate, beveled when over $\frac{1}{8}$ in. in thickness and welded without preheating.

TABLE IV.—APPROXIMATE WELDING RESULTS WITH TYPE H, PRESTO-O-LITE TORCH

Tip No.	Tip Drill Size	Gas consumption Cu. Ft. per hour		Thickness of Metal	Blow-pipe pressures Lbs. per sq. in.		Lineal feet welded per hour
		Oxygen	Acetylene		Oxygen	Acetylene	
1H	69	3 to 4	3 to 4	$\frac{1}{32}$ to $\frac{3}{64}$ in.	2 to 3	2 to 3	30 to 35
2H	60	6 to 8½	6 to 8	$\frac{1}{16}$ to $\frac{3}{32}$ in.	2 to 3	2 to 3	24 to 32
3H	55	10 to 12½	10 to 12	$\frac{1}{8}$ to $\frac{5}{32}$ in	3 to 4	3 to 4	12 to 16
4H	52	12 to 21	12 to 20	$\frac{3}{16}$ to $\frac{7}{32}$ in.	4 to 6	4 to 5	9 to 12
5H	49	18 to 28	18 to 26	$\frac{1}{4}$ to $\frac{5}{16}$ in	5 to 7	5 to 6	6 to 8
6H	44	24 to 40	24 to 38	$\frac{3}{8}$ to $\frac{7}{16}$ in.	8 to 11	8 to 9	4½ to 6
7H	35	35 to 54	35 to 50	$\frac{1}{2}$ in. and up	10 to 15	10 to 14	2 to 3
*7J	35	35 to 54	35 to 50	$\frac{1}{2}$ in. and up	9 to 13	9 to 12	Not used on plates
*8J	31	40 to 60	40 to 55	$\frac{1}{2}$ in. and up	9 to 14	9 to 13	Not used on plates

The General Welding Co.'s Torch.—A welding torch made by the General Welding and Equipment Co., Boston, Mass., is shown in Fig. 30. Each torch is furnished with nine tips, affording a range equal to all ordinary welding jobs. In addition, stems of different lengths may be had. In the illustration, *A* is the body of the torch; *B* is the mixing chamber; *C* is a short stem, the use of which makes the entire torch 16 in. long; *D* is a medium stem, making the torch 22 in. long; *E* is a long stem, making the total length of the torch 30 in.

Details of this torch are shown in Fig. 31. Here the acetylene inlet is shown at *A* and the oxygen inlet at *B*. The body of the torch is indicated by *C*, and *D* is the mixing chamber; *E* is the stem, and *F* various shapes of tips.

Imperial Torches.—Another long-stemmed torch is shown in Fig. 32. This is made by the Imperial Brass Manufacturing Co., Chicago, and differs but little from the one just shown. The gas valves, however are placed at the forward end of the body. Like most of the other torches, these may be used not only for oxy-acetylene, but also for oxy-hydrogen welding work, special tips and regulators being made for the purpose. For oxy-acetylene, the gas pressures are approximately the same

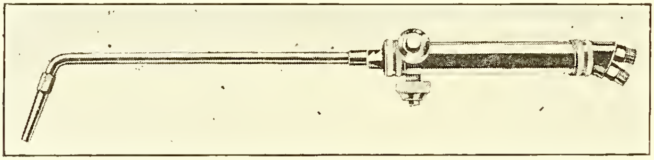


FIG. 32.—The Imperial Type B Welding Torch.

as for other makes of torches. For oxy-hydrogen, the pressures used for various thicknesses of metal and different tips are given in Table V. However, neither the size of the nozzle holes nor the amount of gas used per hour are given. This firm also makes a three-way torch which in outward appearance does not differ from the one shown. It is intended to use a combination of acetylene, oxygen and hydrogen. The method used

TABLE V.—PRESSURE OF GAS USED IN IMPERIAL OXY-HYDROGEN WELDING TORCHES

Welding Tip No.	Thickness of Metal to be Welded, In.	Pressure, Lb. Oxygen	Pressure, Lb. Hydrogen
1H	1/64 to 1/32	10	10
2H	1/32 to 1/16	12	12
3H	1/16 to 1/4	15	15
4H	1/4 to 1/2	20	20
5H	1/2 in. and up	25	25

is to couple the acetylene and hydrogen hose by means of a Y mixing valve from which the two gases are conducted by a single hose to the torch, the oxygen hose being coupled in the usual way. This concern does not recommend the welding of steel above $\frac{1}{4}$ in., or cast iron above $\frac{3}{4}$ in. in thickness with oxy-hydrogen. For light sheet steel, and especially aluminum, oxy-hydrogen has some advantages, provided the hydrogen can be obtained at reasonable rates. The combination of oxygen-acetylene-hydrogen, however, has a claimed temperature of about 5000 deg. F., which is about half-way between that of oxy-hydrogen and oxy-acetylene. It is also claimed that this flame possesses all the advantages of both the double combinations. The same tips are used as for oxy-acetylene, and only a small percentage of acetylene is needed to give a cone-shaped flame of far greater visibility than that of the oxy-hydrogen flame. The low visibility and long flame of the oxy-hydrogen flame are always a handicap in welding to any operator used to employing the oxy-acetylene torch. The approximate pressures employed when using the Imperial three-way outfit are shown in Table VI.

Table VI.—Pressures of Gas Used in Imperial Three-Way Welding Torches
Oxygen, Acetylene and Hydrogen

Oxygen, Welding Tip, No.	Thickness of Metal, to be Welded, In.	Pressures, Lb. Oxygen.	Acetylene,	Hydrogen.
1T	1/32	3	2	2
2T	1/16	5	3	3
3T	3/32	6	4	4
4T	1/8	7	5	5
5T	1/4	8	6	6
6T	3/8	9	7	7
7T	1/2	10	10	10
8T	5/8	12	12	12
9T	3/4	14	14	14
10T	1 in. and over	18	15	15

Calculating Amount of Gas.—It should always be borne in mind, when consulting a table where only pressures are given, that these pressures do *not* signify the *amount* of gas used, and that such pressures apply only to the particular make of torch mentioned. It might be possible for two different torches to use gases at exactly the same pressures as far as the gages indicated, and yet have one of these torches use several times the amount of gases used by the other. In order to make it possible for a user to estimate the *amount* of either oxygen or acetylene his outfit is consuming, three methods of estimating are given here. These methods are taken from the Prest-O-Lite instruction book. Other methods have previously been given in the descriptions of the different gases and their production. The Prest-O-Lite methods are:

Method 1.—Weigh your acetylene cylinders before starting work. Weigh again after the job is completed. Note the difference in weight in ounces, and multiply by 0.9; result equals the cu.ft. of acetylene used. When using Prest-O-Lite torches multiply the acetylene used in cu.ft. by 1.1; the result equals the cu.ft. of oxygen used.

Method 2.—Take readings of oxygen cylinder pressure gage in atmospheres before and after.

For 100-cu.ft. cylinders the difference of readings in atmospheres multiplied by 0.83 equals the oxygen consumption in cu.ft.

For 200-cu.ft. cylinders the difference in readings in atmospheres multiplied by 1.67 equals the consumption of oxygen in cu.ft.

For 250-cu.ft. cylinders the difference in readings in atmospheres multiplied by 2.08 equals the consumption of oxygen in cu.ft.

When using Prest-O-Lite torches, multiply the oxygen used in cu.ft. by 0.91; the result equals the acetylene consumption in cu.ft.

Method 3.—Measure drill size of orifice in torch tip, using standard drills for measuring.

Area of orifice in sq.in. multiplied by 83 equals the acetylene consumption in cu.ft. per minute.

Area of orifice in sq.in. multiplied by 91 equals the oxygen consumption in cu.ft. per minute.

Note the minutes the torch is in use and use the above figures to estimate gas consumption.

Remember, the acetylene consumption cannot be accurately estimated from the pressure gage readings.

In order to simplify the calculations in Method 3, the areas of the various orifices made with numbered drills are given in Table VII. This table was calculated by K. H. Condit, managing editor of the *American Machinist,* for both square inches and square millimeters.

The Rego Welding Torch.—The Rego welding torch is made by the Bastian-Blessing Co., Chicago. The claim is made for this torch that it will not flashback under any condition—even if the tip is immersed in the molten metal, or if the head and tip are heated to a cherry red. The elimination of the flashback is accomplished, not by check valves but by *balancing the pressure of the gases used.* The tips used are of one-piece nickel-copper composition. This gives a harder tip than copper alone. The gases are mixed in the tip as shown in the illustration Fig. 33. By means of an expansion chamber within the tip itself, the gases are reduced in velocity as they come from the

Table VII.—Areas of Drills from 1 to 80 Size in Sq.In. and Sq.MM. Manufacturers Standard

No.	Size of Drill in In.	Area in Sq.In.	Area in Sq.Mm.	No.	Size of Drill in In.	Area in Sq.In.	Area in Sq.Mm.
1	0.2280	0.04083	26.35	41	0.0960	0.007238	4.670
2	0.2210	0.03836	24.77	42	0.0935	0.006860	4.426
3	0.2130	0.03563	22.99	43	0.0890	0.006221	4.014
4	0.2090	0.03431	22.14	44	0.0860	0.005809	3.748
5	0.2055	0.03316	21.39	45	0.0820	0.005281	3.406
6	0.2040	0.03269	21.09	46	0.0810	0.005153	3.325
7	0.2010	0.03173	20.47	47	0.0785	0.004831	3.117
8	0.1990	0.03110	20.06	48	0.0760	0.004536	2.926
9	0.1960	0.03017	19.46	49	0.0730	0.004185	2.700
10	0.1935	0.02940	18.97	50	0.0700	0.003848	2.483
11	0.1910	0.02865	18.48	51	0.0670	0.003526	2.275
12	0.1890	0.02806	18.10	52	0.0635	0.003167	2.043
13	0.1850	0.02688	17.34	53	0.0595	0.002781	1.795
14	0.1820	0.02602	16.79	54	0.0550	0.002376	1.533
15	0.1800	0.02545	16.42	55	0.0520	0.002124	1.370
16	0.1770	0.02461	15.88	56	0.0465	0.001693	1.092
17	0.1730	0.02351	15.17	57	0.0430	0.001452	0.9368
18	0.1695	0.02256	14.56	58	0.0420	0.001385	0.8930
19	0.1660	0.02164	13.96	59	0.0410	0.001320	0.8510
20	0.1610	0.02036	13.14	60	0.0400	0.001257	0.8115
21	0.1590	0.01986	12.81	61	0.0390	0.001195	0.7710
22	0.1570	0.01936	12.49	62	0.0380	0.001134	0.7316
23	0.1540	0.01863	12.02	63	0.0370	0.001075	0.6936
24	0.1520	0.01815	11.71	64	0.0360	0.001018	0.6568
25	0.1495	0.01755	11.32	65	0.0350	0.000962	0.6207
26	0.1470	0.01697	10.95	66	0.0330	0.000855	0.5516
27	0.1440	0.01629	10.51	67	0.0320	0.000804	0.5187
28	0.1405	0.01550	10.00	68	0.0310	0.000754	0.4865
29	0.1360	0.01453	9.374	69	0.0292	0.000669	0.4316
30	0.1285	0.01296	8.361	70	0.0280	0.000615	0.3968
31	0.1200	0.01131	7.297	71	0.0260	0.000531	0.3426
32	0.1160	0.01057	6.819	72	0.0250	0.000491	0.3168
33	0.1130	0.01003	6.471	73	0.0240	0.000452	0.2916
34	0.1110	0.009677	6.243	74	0.0225	0.000398	0.2565
35	0.1100	0.009503	6.131	75	0.0210	0.000346	0.2232
36	0.1065	0.008908	5.747	76	0.0200	0.000314	0.2026
37	0.1040	0.008495	5.481	77	0.0180	0.000254	0.1639
38	0.1015	0.008092	5.221	78	0.0160	0.000201	0.1297
39	0.0995	0.007775	5.016	79	0.0145	0.000164	0.1058
40	0.0980	0.007543	4.866	80	0.0135	0.000143	0.09226

mixing chamber, and just before they issue from the end of the tip. This produces a "soft" flame which melts the metal without blowing it away.

The Oxweld Low-Pressure Torch.—The Oxweld low-pressure torch is of the true injector type. One of this make of torch is shown in Fig. 34 and in detail in Fig. 35. In this torch the acetylene is drawn into the combining tube by the injector action of the high-pressure oxygen jet, in the proper quantity to form what is known as a neutral flame; that is, one

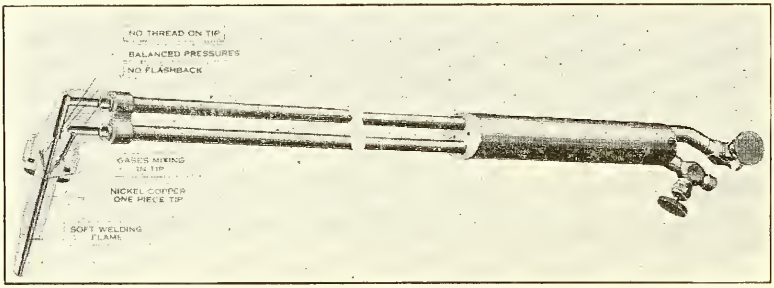


FIG. 33.—The Rego Welding Torch.

not having an excess of oxygen or acetylene. A torch of this type may be used with either a low- or positive-pressure acetylene system, although primarily designed for low-pressure acetylene, which means at a pressure of 1 lb. or less. Ten hard-drawn copper tips, shown in Fig. 36, are regularly supplied for this torch, and bodies may be had to hold the tips

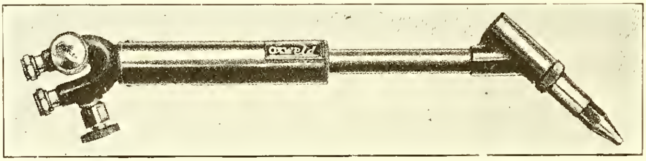


FIG. 34.—The Oxweld Low-Pressure Welding Torch.

at $67\frac{1}{2}$ or 90 deg., although the regular angle is 45 deg. The tips shown are numbered 2, 3, 4, 5, 6, 7, 8, 10, 12 and 15 and are intended for use on metal $\frac{1}{16}$, $\frac{3}{64}$, $\frac{3}{32}$, $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$ and $\frac{3}{4}$ in. thick and up, respectively.

A very light torch, weighing 9 oz. and known as model G, is shown in Fig. 37. This is intended for very light sheet metal, instruments, jewelry and the like. In order to secure a torch of minimum weight, the oxygen and acetylene regulating valves have been removed from the body of the torch and incorporated in a separate valve block which may be fastened in any convenient position near the operator.

Another very light torch is shown in Fig. 38. This is suit-

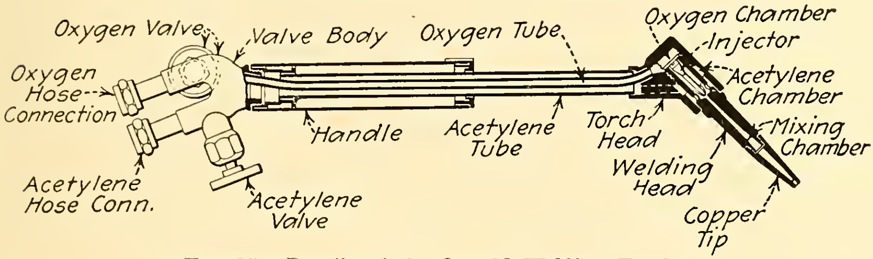


FIG. 35.—Details of the Oxweld Welding Torch.

able for metals up to $\frac{1}{8}$ in. thick. In addition to the usual practice of placing needle valves in the rear body, there is also incorporated in the torch head a needle valve which gives minute control of the flame with each size of tip. Three sizes of in-

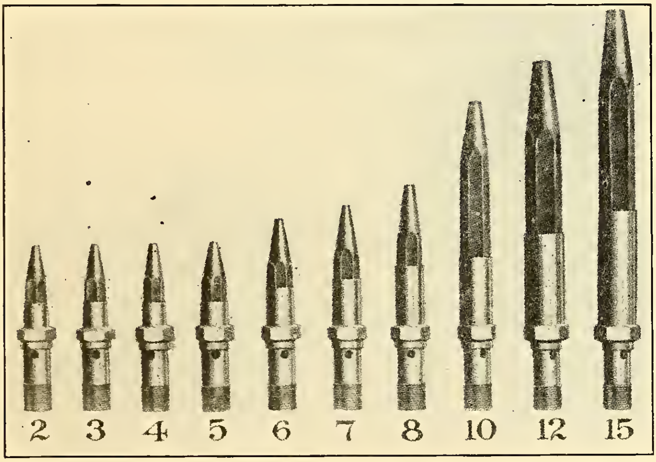


FIG. 36.—A Set of Oxweld Welding Tips.

terchangeable copper tips are supplied. It is 10 in. long and weighs 10 oz.

The Oxweld water-cooled machine torches are shown in Figs. 39 and 40. Fig. 39 is a single-jet, known as type W-8,

TABLE VIII.—APPROXIMATE DATA FOR USE WITH OXWELD WELDING TORCHES

Thickness of Metal In.	Size of Weld. Head	Oxygen Pressure Lb./Sq. In.	Per Hour				Per Linear Foot		
			Speed		Gas Consumption		Gas Consumption		Oxweld Iron Wire Cu. Ft.
			Best Condition Lin. Ft.	Shop Practice Lin. Ft.	Oxygen Cu. Ft.	Acetylene Cu. Ft.	Oxygen Cu. Ft.	Acetylene Cu. Ft.	
1/64 No. 28	Model G	5	30	26	3.5	3.3	0.14	0.13	
1/32 No. 22	2	9	26	22	4.5	4.2	0.20	0.19	0.005
1/16 No. 16	3	10	21	17	6.6	6.2	0.39	0.37	0.01
3/32 No. 13	4	11	17	14	8.7	8.3	0.62	0.59	0.02
1/8 No. 11	5	12	14	11½	10.8	10.2	0.94	0.89	0.04
3/16	6	14	11	9	15.0	14.2	1.67	1.58	0.06
1/4	7	16	9	7	19.2	18.3	2.74	2.62	0.15
3/8	8	19	6¼	4½	27.6	26.3	6.13	5.85	0.3
1/2	10	21	4½	3	36.0	34.3	12.0	11.4	0.6
3/4	12	25	2¾	1½	52.8	50.4	35.2	33.6	1.4
1	15	30	2	1	69.7	66.3	69.7	66.3	2.4

and is adapted to work on cartridge cases, pistol magazines, or any light sheet-metal work that can be fed mechanically. Fig.

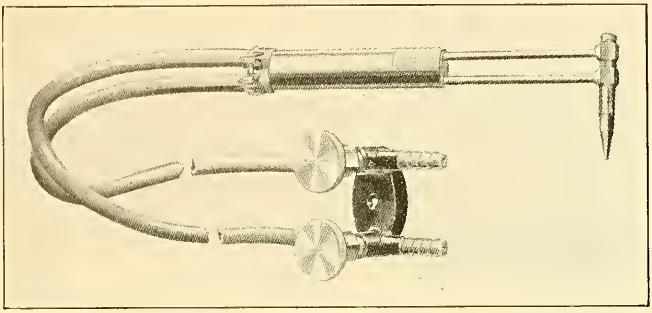


Fig. 37.—The Oxweld Welding Torch Model G.

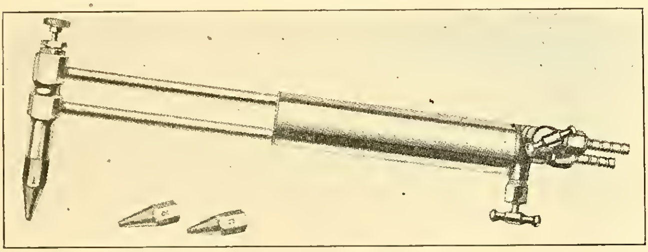


Fig. 38.—The Oxweld Sheet-Metal Welding Torch

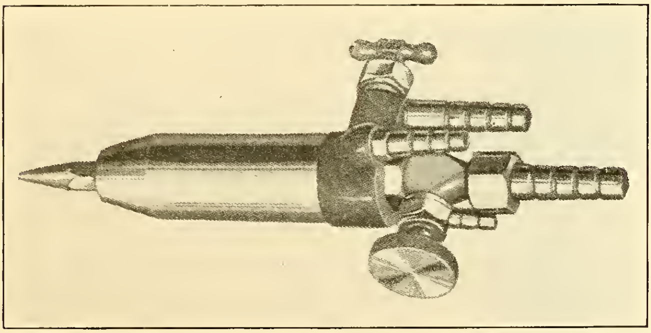


Fig. 39.—The Oxweld Water-Cooled Single-Jet Welding Torch, Type W-8.

40 is known as type W-5, and is a multiple-jet torch suitable for welding metal up to $^3/_{32}$ in. thick, and is designed for con-

tinuous operations on tube stock or other mechanically handled work.

In Table VIII, which is taken from the Oxweld handbook, the various thicknesses of metal, the oxygen pressure, hourly

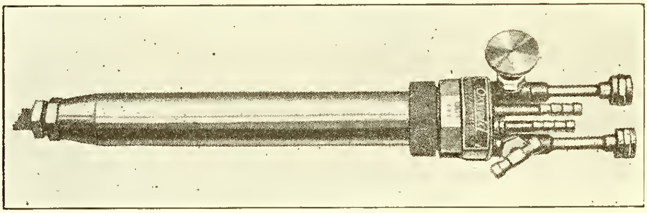


Fig. 40.—The Oxweld Water-Cooled Multiple-Jet Welding Torch, Type W-5.

gas consumption, consumption per foot and amount of wire used, are shown. In this table the acetylene is used at 1-lb. pressure.

The Messer Torch.—The torch shown in Fig. 41 and in

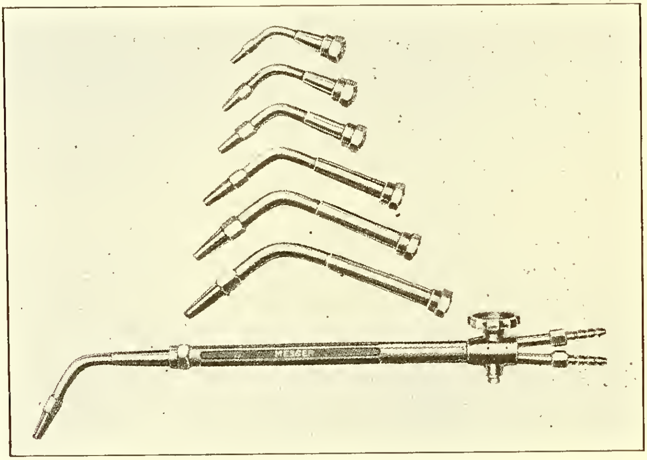


Fig. 41.—The Messer Welding Torch and Tips.

detail in Fig. 42 is made by the Messer Manufacturing Co., Philadelphia, Penn. It works on the injector principle and may be used with either low- or positive-pressure acetylene systems. This make is notable on account of the single valve in the torch itself, and the tips, which are bent, may be set at any angle radial with the torch body. The various sizes, tips and general range are practically the same as for the torches previously described.

The Oxy-Thermalene Welding Torch.—An oxy-thermalene welding torch and a set of tips, are shown in Fig. 43. Details of the head are shown in Fig. 44. One of these torches is about 17 in. long and weighs 24 oz. Referring to the detailed cut, the

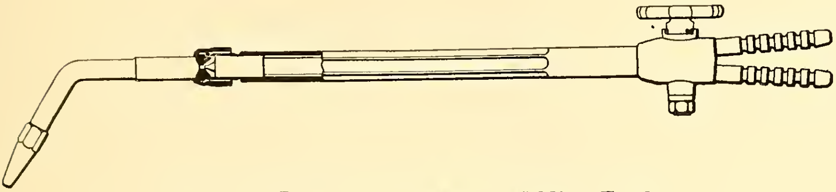


FIG. 42.—Details of the Messer Welding Torch.

oxygen enters at *A* and the thermalene at *B*. The oxygen nozzle is at *C*. Screens are placed at D. One of the troubles with some torches is the fact that frequently a flashback will occur, reaching the oxygen nozzle in the gas chamber. Here a flame would be formed which would burn out the entire copper tip. In the torch shown it is claimed this does not occur. It will be seen that the gas chamber is comparatively large, while

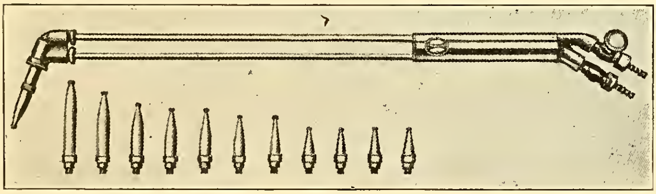


FIG. 43.—A Thermalene Welding Torch and Tips.

the orifice leading from the gas chamber to the mixing chamber is restricted and elongated. This orifice is enlarged abruptly to the mixing chamber in the nozzle, so as to form sharp corners at *E*. The mixing chamber gradually contracts to the outer opening in the nozzle. As a result, if a flashback should occur, it will cause a whirl or eddy at the shoulder *E*, which in itself will prevent the flame from running back through the restricted channel. Moreover, such propagation of the flame into the mixing chamber will cause the gas in the chamber to be pressed back by the increased expansion and pressure, so that there will be only burnt gas in the restricted channel and around the oxygen tip. The result is that the flame will

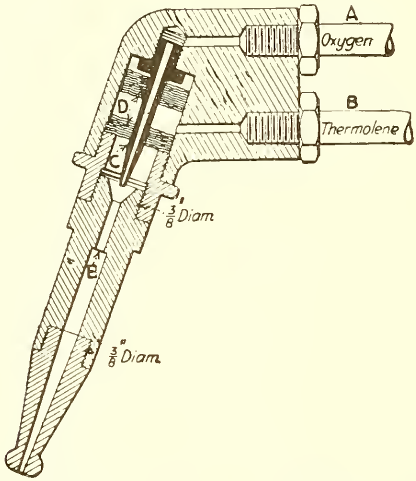


Fig. 44.—Details of the Thermalene Welding Torch Head.

die out in the restricted channel between the gas and mixing chambers, so that a cutting flame is never formed at the oxygen nozzle. It is necessary, however, that these parts should be properly proportioned to obtain the desired results.

Table IX.—Amount of Oxygen and Thermalene Used for Welding

Tip No.	Thickness of Metal in Inches	Consumption of Thermalene, Ft.	Consumption of Oxygen with Thermalene, Ft.	Oxygen Pressure, with Thermalene, Lb.
1	$\frac{4}{64}$ to $\frac{1}{16}$	2.15	2.55	1.0
2	$\frac{1}{16}$ to $\frac{3}{32}$	3.32	3.99	$2\frac{1}{2}$ to 3
3	$\frac{3}{32}$ to $\frac{1}{8}$	5.51	6.52	3 to $3\frac{1}{2}$
4	$\frac{1}{8}$ to $\frac{3}{16}$	8.29	10.11	$3\frac{1}{2}$ to $4\frac{1}{2}$
5	$\frac{3}{16}$ to $\frac{5}{16}$	11.78	14.21	5 to $5\frac{1}{2}$
6	$\frac{5}{16}$ to $\frac{7}{16}$	16.48	20.10	$6\frac{1}{2}$ to $7\frac{1}{2}$
7	$\frac{7}{16}$ to $\frac{5}{8}$	21.40	27.51	10 to 11
8	$\frac{5}{8}$ to $\frac{3}{4}$	25.00	35.01	11 to 12
9	$\frac{3}{4}$ to $\frac{7}{8}$	33.60	54.21	15
10	$\frac{7}{8}$ to $1\frac{1}{4}$	48.05	75.30	20 to 22
11	$1\frac{1}{4}$ to $1\frac{5}{8}$	70.35	101.62	25 to 28
12	$1\frac{5}{8}$ to 2	91.10	159.20	25 to 30

For various welding purposes, 12 sizes of tips are made to be screwed into the torch bodies. These tips run from 2 to 4 in. in length, and the outlets vary from the size of a No. 80

to No. 33 drill. All have $^9/_{16}$-in wrench-holds on them for screwing into the torch bodies.

Table IX will furnish a good idea of the amount of thermalene and oxygen used per hour for different thicknesses of metal, the torch being fitted with the proper nozzle in each case.

CHAPTER VI

GAS CUTTING-TORCHES

The gas cutting-torch is commonly used for cutting through various thicknesses of steel or wrought iron, which are the only metals which can be satisfactorily or economically cut by this process. Cast iron cannot be satisfactorily cut with a gas torch. As an adjunct to a welding outfit, the cutting-torch is used for beveling and for cutting out patches and holes. The process is based on the fact that a jet of oxygen directed upon a previously heated spot of iron or steel, causes it to ignite with the result that the metal, acting as its own fuel, burns away rapidly in the form of iron oxide. This oxide runs, or is blown, out of the cut or kerf produced, in a stream, provided the torch is fed along properly. The same sources of gas supply may be used as for welding, though in some cases other regulators must be employed.

As previously stated, steel and wrought iron are the only metals which can be satisfactorily cut by this process. The reason is that these two metals combine readily with oxygen, with the liberation of heat. The slag is produced at a temperature below that of the melting point of the metal, with the result that it is easily separated from it. Other metals do not produce so much heat when combining with oxygen, and the oxide formed is not reduced to a molten condition at temperatures below that of the melting point of the metal, with the result that it cannot be easily separated.

The combination of the oxygen with the iron is not that of complete combustion. An examination of the slag produced shows the presence of metallic iron, which leads to the belief that the oxidation follows the grain surfaces of the metal and more or less mechanically disintegrates the mass at the line of cutting.

Cutting torches use a single high-pressure oxygen jet for the cutting. This jet has one or more heating jets in line with, or surrounding it.

Since the temperature to which it is necessary to heat the iron or steel, in order to have the oxygen act, is comparatively low (about 900 deg. F.) a number of gases may be used for heating. Oxy-acetylene is very commonly used on account of its convenience, for ordinary work. For heavy work oxy-hydrogen is used on account of its longer flame and because no products of combustion that hinder cutting are produced. The temperature required is well within its heating range, and steel up to 36 in. thick has been cut. The thicker the metal the greater the pressure of oxygen used, as will be seen

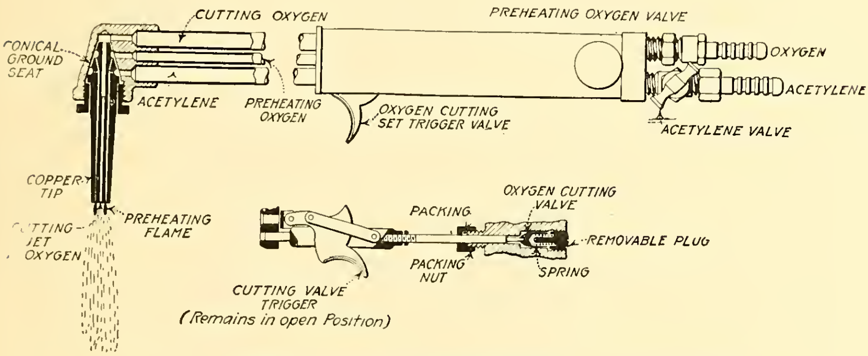


FIG. 45.—Details of the Davis-Bournonville Cutting Torch.

from the various tables. In the cutting torches, the holes for the various jets are usually drilled in the same tip, though in some cases separate tips, set close together, are used. The ordinary cut or kerf made by the cutting torch is from $^1/_{16}$ to $\frac{1}{8}$ in. wide, according to the size of the oxygen jet used.

Since the same construction of the heating part of a cutting torch is used as in the welding torch, it naturally follows that both the positive-pressure and low-pressure, or injector types of heating units are used in conjunction with the single oxygen cutting jet.

The Davis-Bournonville Cutting Torches.—The details of a Davis-Bournonville, No. 3000, cutting torch are shown in Fig. 45. This is typical of the general principle on which all of this firm's cutting torches are made. In use, the positive-pressure heating unit is first started and applied to the work to be cut. As soon as the metal reaches a red heat, the trigger is pressed and the oxygen jet commences its work. This particular model of torch is supplied with five interchangeable tips, and the cutting jet of oxygen may be turned on or off by a simple pressure of the trigger, as just mentioned. This trigger is so made that it is not necessary to keep the finger on it all the time it is in use. There are only two hose connections for the gases, one for oxygen and one for acetylene.

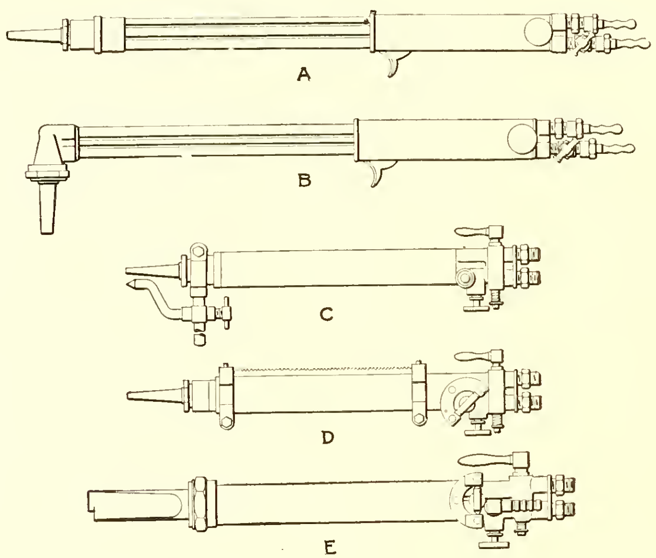


Fig. 46.—Various Models of the Davis-Bournonville Cutting Torches.

The pressures of the respective gases vary with the thickness of the metal being cut, which may be from $\frac{1}{8}$ up to 12 in. or more. The torch is 20 in. over all, and is especially adapted to freehand cutting, and in wrecking or scrapping metal.

A number of different styles of cutting torches are shown in Fig. 46. *A* is a straight-head cutting torch (No. 2018) which may be fitted with curved tips for cutting boiler tubes, rivet heads, etc. Three bent and two straight tips are regularly furnished. In general, it closely resembles No. 3000.

The torch *B*, known as No. 1316, is very much like the first torch described, except it is intended for use with oxy-

STYLE No.	STYLE of TIP	ILLUSTRATION	SIZES									REMARKS
7	OXY-ACETYLENE BOILER TUBE TIP		1	2	3	4						
10	OXY-ACETYLENE WRECKING TIP		1	2	3	4						
12	REGULAR STYLE "C" CUTTING TIP		1	2	3	4	5	6	7	8	9 10	TWO HEATING HOLES
15	OXY-HYDRIC HAND CUTT. TIP		2	3	4	5						WILL CUT FROM 6"–16"
16	OXY-HYDRIC MACH. CUTT. TIP		2	3	4	5	6					WILL CUT FROM 6"–24"
25	STYLE "C" OXY-AC. CUTTING TIP		2-1	2-2	2-3	3-1	3-2	3-3 3-4	3-5 3-6	3-7 3-8	3-9 3-10	4 HEATING HOLES
26	STYLE B.C. CUTTING TIP		1	2	3							FOR BILLET CUTTING ONLY
29	MULTI. FLAME B.C. CUTTING TIP		2									
35	STYLE "C" CUTTING TIP		4-1	4-2	4-3	4-4	4-5	4-6	4-7	4-8	4-9 4-10	FOR CARBO-HYDRIC CITY-NATURAL GAS
206	OXY-ACET. PL. CUTTING TIPS		2	3	4							
207	OXY-HYDRIC PL. CUTTING TIP		2	3	4							
208	OXY-HYDRIC BENT WRECKING TIP		2	3	4							

STYLE No.	STYLE of TIP	ILLUSTRATION	SIZES									REMARKS
674	OXYGRAPH CUTTING TIP		1	2	3	4	5					5 HEATING HOLES
1511	REG. OXY-HYDRIC CUTTING TIP		1	2	3	4						
1567	LARGE OXY-HYDRIC CUTTING TIP		1	2	3	4	5					
1568	LARGE OXY-HYDRIC BENT CUTTING TIP		1	2	3	4	5					
1678	OXY-HYDRIC CUTTING TIP		1	2	3	4	5					"ALCO"
1967	CITY GAS TIP CHICAGO STYLE		1									INJECTION TYPE
2017	PANAMA CUTTING TIP		2									7" LONG 2 HEATING HOLES
2113	STYLE "A" TIP		1	2	3							FOR CUTTING ATTACHMENT
2133	OXY-HYDRIC HAND CUTTING TIP		2	3	4	5						"ALCO"
2272	PANAMA CUTTING TIP		3	4								7" LONG 4 HEATING HOLES
2690	OXY-HYDRIC CUTTING TIP		1	2	3	4	5	6	7	8	9	G. E. CO.

FIG. 47.—Different Tips for Use with the Davis-Bournonville Cutting Torches.

hydrogen. Torch *C* (No. 471) is a circle cutting torch fitted with a 15-in. radius rod adjustable for various sizes of circles. It uses either oxy-acetylene or oxy-hydrogen for heating, and takes all standard size tips. It is the standard torch for nicking billets for breaking. It may be had fitted with special adjustable holder, rack and pinion, for machine cutting.

TABLE X.—GAS PRESSURES USED WITH THE DAVIS-BOURNONVILLE STYLE C CUTTING TORCHES, USING STYLE 12 TIPS

Tip No.	Thickness of Metal Inches	Acetylene Pressure Lbs.	Oxygen Pressure Lbs.
1	1/8	3	10
1	3/16	3	15
1	1/4	3	20
1	5/16	3	20
2	1/4	3	10
2	1/2	3	20
2	3/4	3	30
2	1	3	35
3	1	4	30
3	1 1/2	4	40
3	2	4	50
3	3	4	60
4	3	5	60
4	4	5	70
4	5	5	85
4	6	5	100
5	6	6	90
5	7	6	100
5	8	6	125
5	10	8	150

Torch *D*, No. 640, is a machine cutting torch for use with the different cutting machines made by the Davis company. It is fitted with an electric switch and shut-off valve which automatically starts the cutting-machine feed when the oxygen cutting jet is turned on, without the necessity of readjusting pressures or the heating flame. It uses all standard-size cutting tips and special Oxygraph and Radiograph tips. A larger and heavier torch of similar design and construction for oxy-hydrogen machine work is shown at *E*. This is known as No. 1314. Larger sizes, or special torches used for cutting, are water-cooled. Tips of various styles, for different purposes, which may be used with the torches mentioned, are shown in Fig. 47.

The approximate oxygen and acetylene pressures used in

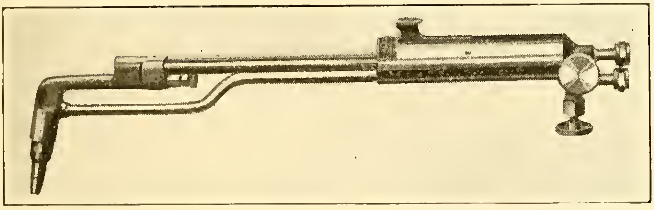


FIG. 48.—The Oxweld Cutting Torch, Model B.

the Davis style C cutting torches, using style No. 12 tips, are given in Table X. As in welding, these pressures are only general guides for the make of torch mentioned, and the skilled operator usually adjusts his flame regardless of the

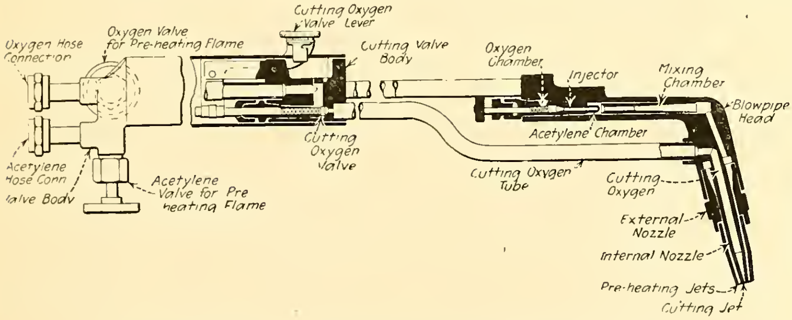


FIG. 49.—Details of the Oxweld Cutting Torch, Model B.

tables given, since a neutral heating flame is essential at all times for satisfactory results.

Oxweld Cutting Torches.—An Oxweld low-pressure or injector type of cutting torch is shown in Fig. 48. This is their model B. Details are shown in Fig. 49. In this torch, the cutting jet is entirely surrounded by the preheating flame, as the oxy-acetylene is delivered through six openings arranged in a circle around the orifice for the oxygen jet. This arrangement makes it possible for the preheating flame to always precede the cutting jet, no matter in what position the torch is held, or in whatever direction the cut is made, be it horizontal, transverse, circular, elliptical, toward or away from the operator. In so working, the operator does not have to shift his postion or turn the torch. This is especially valuable in wrecking steel structures, removing risers from steel castings, or cutting steel scrap, especially where places difficult of access are encountered. The preheating flame is produced in practically the same way as in the welding torch previously shown.

There is a separate valve for controlling the oxygen to the preheater, which enables the operator to secure close adjustment and avoid waste of gas. The oxygen-jet valve is of the

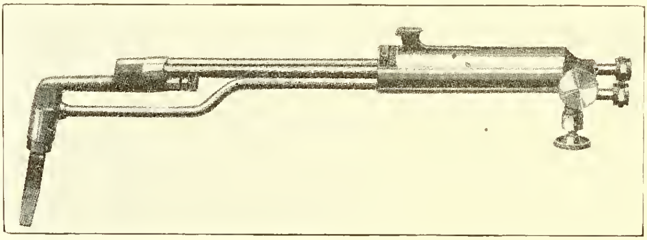


Fig. 50.—The Oxweld Cutting Torch with a Rivet-Head Cutting-Nozzle.

plunger type, which is so constructed that its movement produces no tendency to deflect the cutting jet from the line of the cut. The location of the valve lever is on top of the handle and its motion is in the direction of the vertical center plane of the torch. The valve is held open for continuous cutting, when desired, by a simple but effective button-like latch, which may be instantly engaged or released by a slight movement of the thumb. The external nozzle is furnished with a copper tip. The internal nozzle is held in place by tightening the external nozzle. To remove the former it is only necessary to unscrew the external nozzle. This torch is regularly furnished with four interchangeable tips, for cutting up to 1 in.; from 1 to 3 in.; from 3 to 6 in.; and from 6 in. up.

A model-B torch fitted with a special rivet-head cutting nozzle is shown in Fig. 50. Another form, known as model

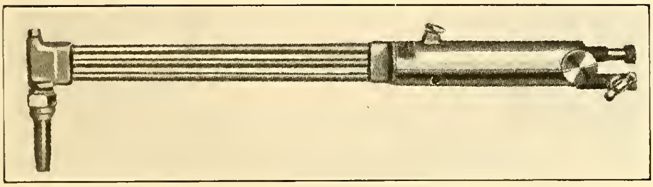


Fig. 51.—The Oxweld Cutting Torch for Ship Work.

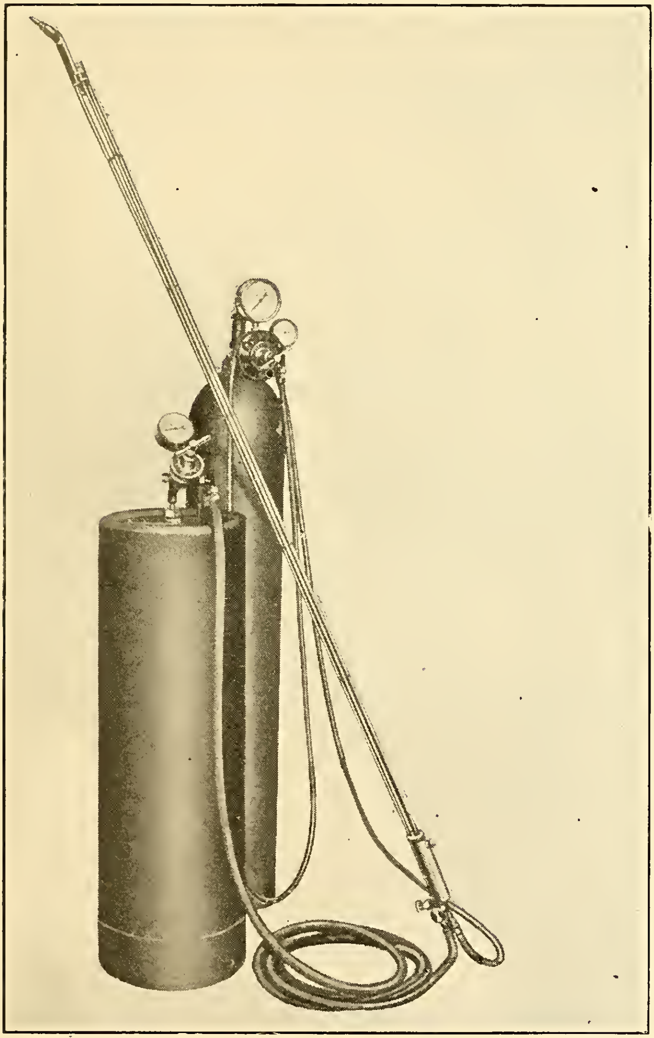


Fig. 52.—The Oxweld Staybolt Cutting-Torch.

C-6, is shown in Fig. 51. This was made to meet the demand for a light, rugged and adaptable cutting torch for work on double bottoms and below decks of ships. In general, it closely resembles the other models. It weighs $2\frac{3}{4}$ lb. and is 20 in. overall.

For cutting inner and outer shells of locomotive fireboxes, where length and slenderness is necessary, the staybolt cutting torch shown in Fig. 52 has been made. This is, however, merely a special form of the model B. The long "stem" is made up of three gas tubes as shown. This torch is regularly furnished in 42, 54, 69 and 84 in. lengths to suit the needs of the user. The 84-in. torch weighs $6\frac{1}{4}$ lb. The head is set at an angle of 20 deg., which experience has shown is the more generally useful. All the regular nozzles can be used with this torch.

In addition to the torches mentioned, the Oxweld Acetylene Co. makes straight-tipped machine cutting torches, which may be used on any of the cutting machines on the market. Like all other cutting torches, small guide wheels may be used for steadying the torch when cutting to straight, irregular or circular lines by hand.

In Table XI are given the oxygen pressures and amount of gas consumption for various thicknesses of metal. The acetylene pressure is the same as for welding, 1 lb. With the data given in this table, and knowing the cost of acetylene and oxygen, the approximate cost of gas for any given job may be calculated with a fair amount of accuracy and serve as a basis for price estimates. It must be kept in mind that old rusty metal, like boiler plate, will take much more gas than will clean metal.

Other Cutting Torches.—In order to give the reader an idea of the construction of some of the other well-known cutting torches, a few will be shown. Fig. 53 shows details of a cutting torch made by the Messer Manufacturing Co., Philadelphia. This type of torch will use either medium or low-pressure acetylene, as it works on the injector principle which is independent of the acetylene pressure. The oxygen jet is operated by means of the lever shown on top. The wheel guides are adjustable so that the tip may be kept the proper distance from the work.

TABLE XI.—OXWELD CUTTING DATA

Thickness of Metal In.	Size of Internal Nozzle	Oxygen Pressure Lb./Sq. In.	Per Hour				Per Linear Foot	
			Speed		Gas Consumption		Gas Consumption	
			Machine Lin. Ft.	Hand Lin. Ft.	Oxygen Cu. Ft.	Acetylene Cu. Ft.	Oxygen Cu. Ft.	Acetylene Cu.Ft.
1/8		10	120	90	28	7.8	0.31	0.09
1/4		15	93	74	37	11.3	0.50	0.15
3/8	No. 1	20	81	62	48	14.2	0.67	0.23
1/2		25	73	55	58	16.3	1.05	0.30
3/4		30	63	46	80	19.7	1.74	0.43
1		35	57	40	100	22.0	2.50	0.55
1 1/4		35	53	36	120	23.6	3.33	0.66
1 1/2	No. 2	40	50	33	141	25.3	4.27	0.77
2		45	46	29	184	27.7	6.34	0.96
3		55	41	24	268	31.9	11.2	1.33
4		65	36	20	352	35.6	17.6	1.78
5	No. 3	75	32	17	436	38.8	25.7	2.28
6		85	29	15	522	41.5	34.8	2.76
8		95	23	11	698	46.2	63 4	4.2
10		115	18	8	880	50.3	110.0	6.3
12	No. 4	135	15	6	1080	53.9	180.0	9.0
14		155	12		1290	57.3		
16		175	10		1520	60.4		
	Rivet Nozzle	40			240	25.0		

The construction of the cutting torch made by the General Welding and Equipment Co., Boston, Mass., is shown in Fig. 54. The valve lever for the cutting jet has a lock that is easily manipulated with the thumb. This torch will use either medium- or low-pressure acetylene, and like the other torches, will use either acetylene or hydrogen with the oxygen. The

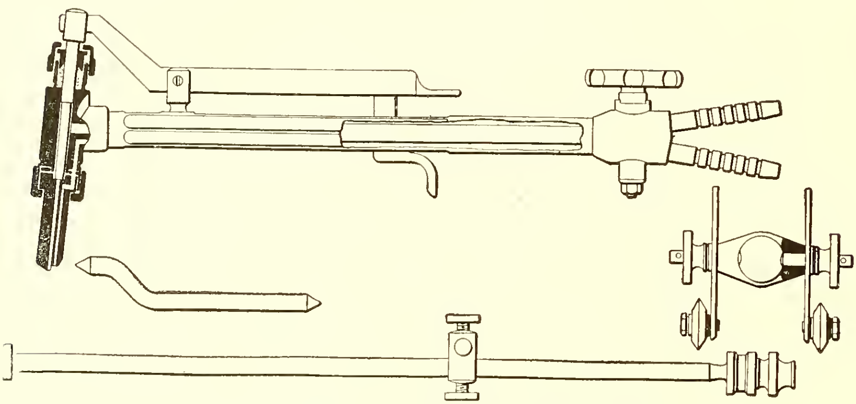


FIG. 53.—Details of the Messer Cutting Tools.

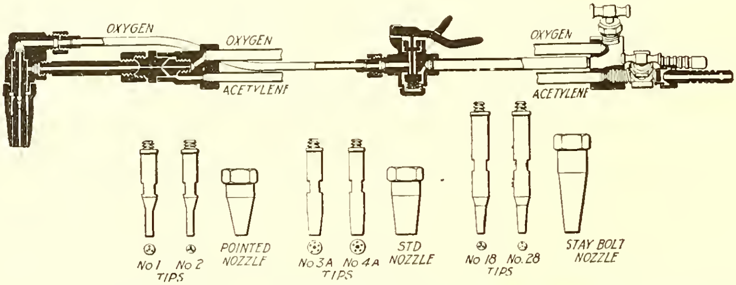


FIG. 54.—Details of the Cutting Torch Made by the General Welding and Equipment Co.

parts are easily changed when necessary. The head is fastened to the mixing chamber by means of a ground-joint swivel and loose-nut coupling. The swivel is brazed into the head so as to make a tight joint even under heat. The mixing chamber can be easily taken out and cleaned. The lever key is accessible from all sides and the seat can be replaced in a few minutes.

As has been previously mentioned, the consumption of the various gases for different work can be only approximately estimated beforehand, as so many elements enter into the work. Even in cutting the same piece, if the cut is of any length, the gas consumption and time will often vary to a marked extent from different causes. Parts may be clean and others rusty. The operator's skill will vary as he is fresh or tired, and many other reasons may enter into the calculations. However, tabulations of specific results may often be of considerable value. Those already given have been for average conditions, and are believed to be as near correct as it is possible to get them. The company making the torch last mentioned has made some calculations regarding the time taken to cut clean metal, which will be of interest. On $\frac{1}{2}$-in. steel, the time for cutting 1 ft. with a regular machine cutting tip, was 0.67 min. and by hand, 0.90 min.; for 1-in. steel, 1.25 and 1.50 min. respectively; for 2 in., 1.40 and 1.60 min.; for 4 in., 1.50 and 2.00 min.; for 6 in., 3.00 and 4.00 min. and for 8 in., 3.25 and 4.50 min.

An 8-in. steel shaft was cut through in 3 min., using 14 cu.ft. of oxygen; an 18-in. shaft was cut in 16 min. with 250 cu.ft. of oxygen; a 20-in. shaft in 18 min. and 300 cu.ft. of oxygen. For the last two oxy-hydrogen was used.

The cutting of steel risers and shafts, under what is claimed to be average conditions, is tabulated as shown in Table XII. The tests are classified as follows:

Table XII.—Cutting Steel Risers With the General Welding and Equipment Co. Torches

Test No.	Shape of cut	Number of cuts made	Total square inches cut	Total oxygen consumption, cu. ft.	Square inches cut per cu. ft. oxygen	Square inches cut per minute	Time, minutes
1	Different shapes, 1 in. to 5 in. thick	40	615	248	2.84	—	—
2a	Wheel rim 1⅝ in.	10	94.5	8	11.8	22.5	4.17
2b	to 2½ in. thick	10	100.6	10.4	9.67	18.3	5.5
3	6½ in. x 8 in.	1	52	14	3.7	27.1	1.92
4	5 in. x 10 in.	1	50	18	2.78	20	1.5
5	5½ in. x 15½ in.	1	85.25	34	2.5	22.8	3.75
6	5½ in. x 15½ in.	1	85.25	28	3.04	26.2	3.25
7	5½ in. x 16½ in.	1	90.75	32	2.84	27.9	3.25
8	11 in. x 11 in.	2	242	112	2.16	—	—
9	6 in. diameter	4	113	46	2.48	11.3	10.00
10	15 " "	1	177	162	1.1	12.6	14.00
11	16 " "	1	200	200	1.0	14.3	14.00
12	18 " "	1	254	250	1.0	15.9	16.00
13	20 " "	1	314	300	1.05	17.3	18.00

Test No. 1 comprises ordinary work as it came along. Risers were not clean and especially the smaller risers had sand and holes in the core. The oxygen consumption contains all the waste changing from one piece to another.

Test No. 2a was made on clean metal with oxy-acetylene and with a special pointed tip.

Test No. 2b was the same as No. 2a but cut with oxy-hydrogen, a regular tip being used.

Test No. 3 was made on a very clean riser. The operator could rest his hand very comfortably. The cut looked as if it was done by machine.

Tests Nos. 4-7.—Cuts were made on risers of a 20-ft. flywheel. Cleaning was only superficially done and operator was in a fair, but not ideal position. One riser showed a large blow-hole. The cuts were clean through.

Test No. 8.—Two cuts were made on the same flywheel. Risers were well-cleaned, but the cranes could not be spared to bring the face of the risers into a horizontal line. They had to be cut diagonally and the operator had to bend so far over that with the first riser he lost his balance and fell and had to interrupt the operation, therefore, no time was taken. The maximum thickness of the cut was 13 in. The cuts were clean through.

Tests No. 9-13.—Cuts were made on risers of circular shape. The number of sq.in. cut per cu.ft. of oxygen is in the average lower than with rectangular shapes, as it is too cumbersome to regulate the oxygen pressure according to the varying thickness. It does not pay to start with lower pressure at the beginning and increase it the more the cutter is nearing the center or full thickness of the metal. Moreover, the cuts were made with a two-line cutting torch so that the preheating flames would have suffered with regulating the oxygen pressure in such wide limits. With the heavier cuts of 15 in., 16. in., 18 in. and 20 in. thickness, the principal consideration was to cut through rather than to get stuck, and not look too close to the oxygen consumption.

The Imperial Brass Manufacturing Co., Chicago, makes the cutting torches shown in Fig. 55. These are of the positive-pressure type. *A* is a combination cutting and welding torch, the oxygen pipe and tip being detachable, so that the curve tip may be put on when the torch is wanted for welding. *B* is a cutting torch only. Either may be used for oxy-acetylene or for oxy-hydrogen. When using oxy-hydrogen, the respective pressures are given in Table XIII.

The torches may also be used for the company's three-way gas system, which uses a combination of acetylene, hydrogen, and oxygen, as explained under welding torches. The acety-

TABLE XIII.—PRESSURES FOR OXY-HYDROGEN CUTTING WITH IMPERIAL TORCHES

Cutting Tip	Thickness of Wrought Iron or Steel to be Cut, In.	Pressures: Oxygen, Lb.	Pressures: Hydrogen, Lb.
1H	1/8 to 2	30 to 40	5 to 10
2H	2 to 4	50 to 70	10 to 15
3H	4 to 6	80 to 100	15 to 20
4H	6 to 9	100 to 125	20 to 25
5H	9 to 12	125 to 150	25 to 30

These figures represent minimum and maximum pressures. For intermediate thicknesses use pressures in proportion.

lene and hydrogen are mixed through a Y-valve and enter the torch through the same hose. Pressures when the gases are used in this way are shown in Table XIV.

TABLE XIV.—PRESSURES WHEN USING THREE-WAY GAS SYSTEM

Cutting Tip, No.	Thickness of Steel or Wrought Iron to be Cut, In.	Pressures: Oxygen, Lb.	Pressures: Acetylene, Lb.	Pressures: Hydrogen, Lb.
1T	1/8 to 2	30 to 40	5	5 to 10
2T	2 to 4	50 to 70	5	10 to 15
3T	4 to 6	80 to 100	10	15 to 20
4T	6 to 9	100 to 125	10	20 to 25
5T	9 to 12 and over	125 to 150	15	25 to 30

The Carbo-Hydrogen Co., Pittsburgh, Penn., makes two models of the injector-type hand cutting torches, shown in Figs. 56 and 57, and in detail in Fig. 58. They also make straight-nozzle machine torches. Mechanical guides, or wheels, may be had for attaching to the regular hand models, or to the straight-nozzle torches. Tips are furnished in a number of interchangeable sizes and shapes. They are made from a solid brass bar, with an outer shell of copper solidly attached with rivets. The preheating holes are arranged closely around the cutting orifice so that the flame cones do not have a tendency to melt edges of the cut. It is claimed that the tips remain cool and do not have to be dipped in water to keep them cool when used for long periods. The regular sizes of the tips are arranged for cutting from the thinnest metals up to 18 in. in thickness, or more with special tips. The head and base castings of the torches are of Tobin bronze and the tubes are of seamless drawn steel, surrounded by an aluminum or a fiber handle. A special swivel-point valve stem, instead of the usual solid needle point, is used for controlling the

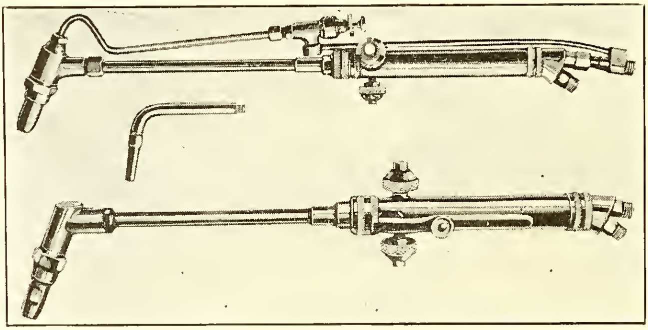


FIG. 55.—The Imperial Cutting Torches

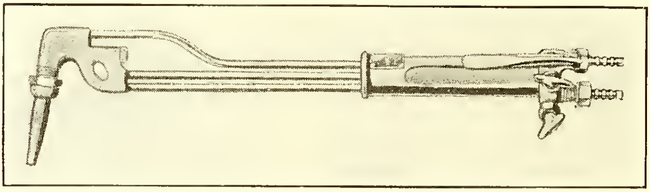


FIG. 56.—Carbo-Hydrogen Model C Cutting Torch

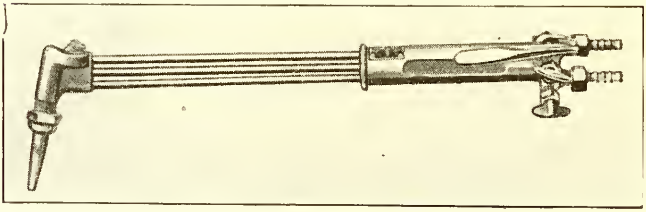


FIG. 57.—Carbo-Hydrogen Model B Cutting Torch.

combustion gas. All parts are easily removed for cleaning, and the injector may be taken out with a pair of pliers. These torches are designed for use with oxy-carbo-hydrogen gas. Carbo-hydrogen is a fixed gas, permanent under all weather conditions. Since it does not solidify there is said to be no residue left in the tanks or cylinders at any time. It is clean, easy to use, and safe, since it is combustible but not explosive within itself. It is a product of the destructive distillation of suitable hydro-carbons, and has a general analysis of 85 per cent hydrogen and 15 per cent light hydro-carbons. It is claimed that this gas has no tendency to harden the surface of the metal being cut. It is not a sensitive gas, and backfiring is rare. It is marketed in steel cylinders under 1800 lb. pres-

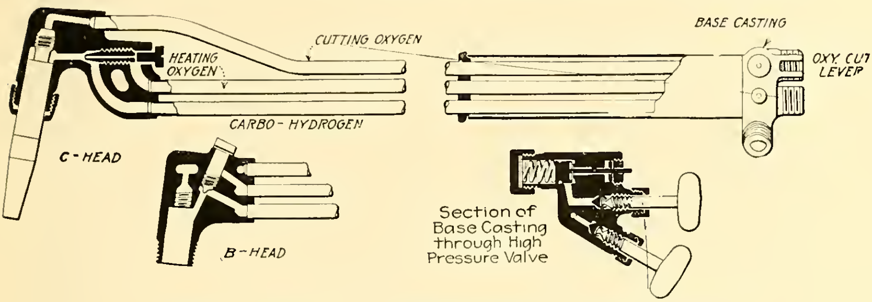


FIG. 58.—Details of Carbo-Hydrogen Cutting Torches.

sure and of about the usual capacity. The pressure is reduced to from 5 to 10 lb. for working purposes, 5 lb. being the pressure usually employed.

In Table XV are shown the approximate number of feet cut per hour, the pressure of the oxygen and the amounts of the gases used per lineal foot of cut. The carbo-hydrogen pressure is 5 lb. in each case.

TABLE XV.—GAS CONSUMPTION AND PRESSURES WHEN USING OXY-CARBO-HYDROGEN CUTTING-TORCHES. THE CARBO-HYDROGEN PRESSURE IS ABOUT 5 LB. IN EACH CASE

Thickness of Steel in Inches	Size of Cutting Tip	Lineal Feet Cut per Hour by Hand	Pressure of Cutting Oxygen in Pounds	Cu. Ft. of Oxygen Used per Lineal Ft. of Cut	Cu. Ft. of Carbo-Hydrogen Used per Lineal Ft. of Cut
¼"	1 A	110	15	1	1
½"	2	90	25	1⅔	1
¾"	2	75	32	2⅓	1½
1"	2	60	35	3	1½
1½"	3	45	45	4⅔	2½
2"	3	38	50	7	3½
3"	3	28	60	14	6
4"	3-A	18	75	26	9
5"	4	13	85	32	12
6"	4	11	100	40	13
7"	5	8	120	50	13
8"	5-A	7	140	64	14
9"	5-A	6	160	78	16

Above pressures can be increased at times on various grades of steel advantage.

The Rego cutting torch is made by the Bastian-Blessing Company, Chicago. Like the "balanced pressure" welding torch made by this concern, it is claimed that the cutting torch cannot be made to flashback while in use. Details of the mechanism are shown in Fig. 59. The tip is of nickel-copper composition and mates with a ground joint to which it is held

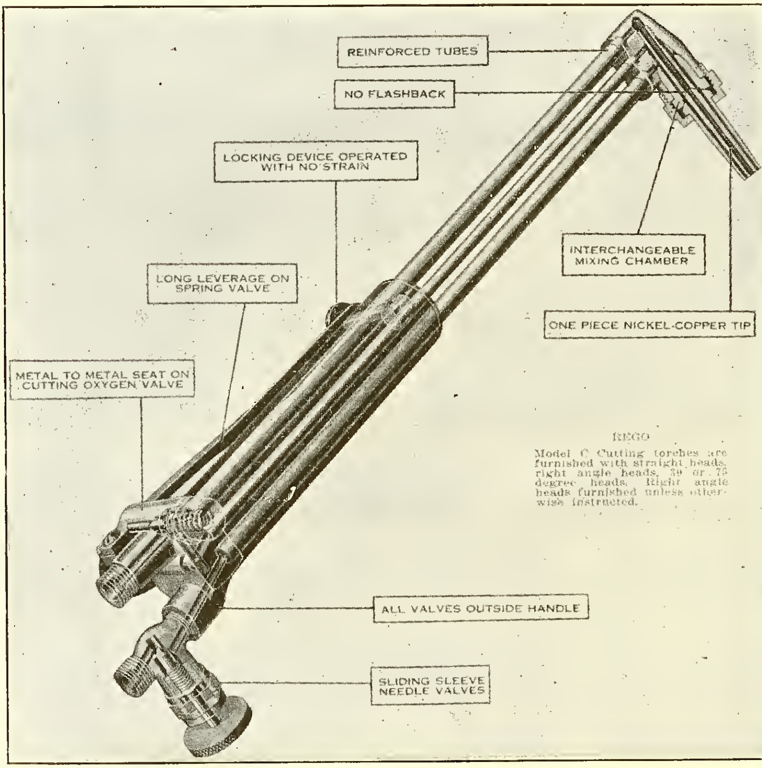


Fig. 59.—Rego Cutting Torch.

by a union nut. The mixing chamber is easily renewable. All valves are outside and easy to get at for repacking or regrinding. The high pressure oxygen valve seat is metal to metal, and it is controlled by a powerful spring and is operated by a long lever acting on a plunger, like the valve of a gasoline motor. The operating lever is easily locked so there is no strain on the operator's hand.

Combination Torches.—Several companies make combination welding and cutting torches. These usually consist of a

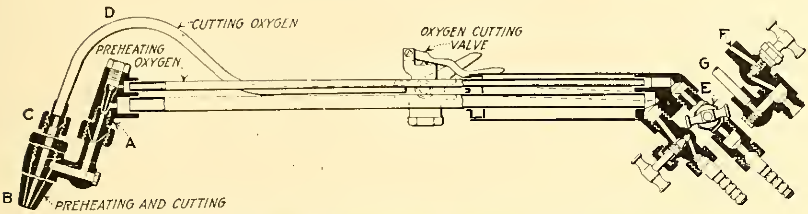


Fig. 60.—Airco-Vulcan Combination Cutting and Welding Torch.

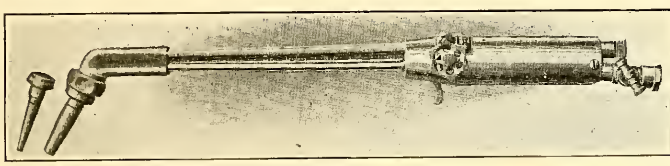


Fig. 61.—Milburn "Cut-Weld" Torch.

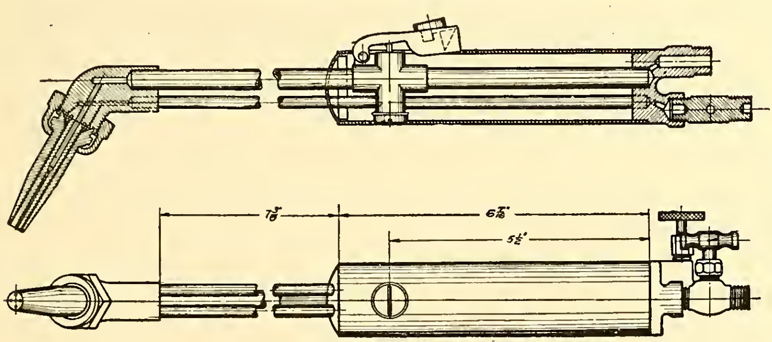


Fig. 61A.—Details of Milburn Torch.

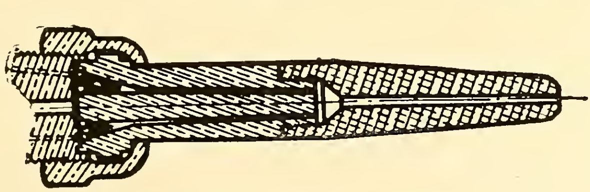


Fig. 61B.—Details of Torch Tip.

cutting attachment for the welding torch. As a commercial proposition, such combinations are usually not to be recommended, but where an operator occasionally has to shift quickly from welding to cutting, they may sometimes be used to advantage. Along with their regular lines of welding- and cutting-torches, the Air Reduction Sales Co., N. Y., put out the combination torch shown in detail in Fig. 60. This is known as the Airco-Vulcan cutting and welding torch, and it well illustrates the general principles of this kind of a torch. The main body is that of the regular Airco-Vulcan welding torch. The regular welding tip is removed from *A* to receive the connection of the special tip *B*. This tip is connected at *C* to the high-pressure oxygen tube *D*. A combination valve is screwed into the torch body at *E* in place of the single oxygen valve used for welding. This valve has a passage at *F* for the preheating oxygen and one at *G* for the cutting oxygen that goes out through *D*. The preheating flame surrounds the cutting jet as in other regular cutting torches, so that an operator

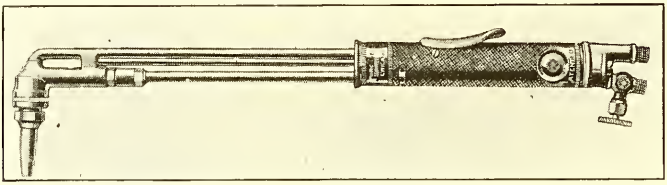


FIG. 62.—Torchweld Gas Cutting-Torch.

may cut circles or angles without altering the direction of the torch body to any extent.

The Milburn Combination Torch.—The "Cut-Weld" torch made by the Alexander Milburn Co., Baltimore, Md., is shown in Fig. 61. This torch is made into either a cutting or a welding torch by merely changing the tips. The illustration shows a cutting tip in place and a welding tip just at the left. The regular size is 19 in. long and weighs 2¾ lb. Details of the torch, with a cutting tip in place, are shown in Fig. 61A. Details of a welding tip are shown in Fig. 61B.

In tests in Washington before engineers of the Stone & Webster Corp. and several government officials, a 12 in. steel billet was cut through in 6½ min., which includes ½ min. for preheating. A test was made to determine its resistance to backfire and though the tip was nearly burned off, no flashback took place. A hole was also blown through a 5 in. steel billet in 40 sec. with no flashback.

Torchweld Gas Cutting-Torch.—The gas cutting-torch shown in Fig. 62 is made by the Torchweld Equipment Co., Fulton and Carpenter Sts., Chicago, and is known as their style 15 MC. It is designed to use oxy-acetylene, oxy-hydrogen, or oxy-hydrocarbon gases, such as butane, calorene, and the like. Special tips, however, are needed for the various gas combinations. An 85-deg. torch-head angle is standard but 70, 50, 35 and straight heads can be furnished when desired.

A one-piece cutting tip is used and the mixing chamber is just back of the torch head. A novel feature of the construction is that an annular space is provided around the mixer in which a small amount of gases accumulate. Drill holes connect this space with the gas passage-way leading to the tip and, in case of backfire to the mixing chamber, the ignited mixture in the annular space is designed to blow out the back-

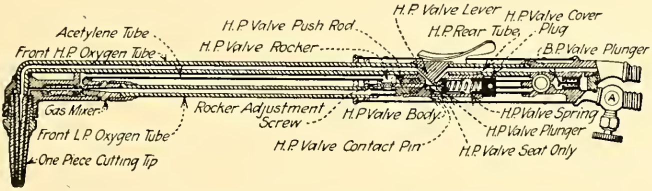


Fig. 62*A*.—Details of Torchweld Cutting Torch.

fire and eliminate the hazard of flashbacks into the flexible connecting hose.

All the gas-tight seats in tips, needle valves and connections, are of the line-contact type: In other words, a convex surface is brought into contact against either a flat surface or another convex surface. A tight seating is thereby much more easily obtained than by using two flat surface contacts.

One of the difficulties experienced with two-hose type cutting torches is the back pressure of the acetylene into the oxygen hose. Under certain conditions this results in the oxygen hose becoming filled with mixed gases which ignite at the tip and a more or less serious flashback into the oxygen hose is unavoidable.

The Torchweld back-pressure valve is claimed to prevent the acetylene from entering the oxygen hose, since a certain pressure on the oxygen is necessary in order to open this valve, and as the acetylene pressure also tends to close the valve still tighter.

Details of the construction of this torch are shown in Fig. 62A.

CUTTING UNDER WATER WITH A GAS TORCH

A number of torches have been developed for cutting under water. One of these has been successfully used at the Puget Sound Navy Yard, Washington State, for some time, and was made by putting a special hood over the tip of a regular

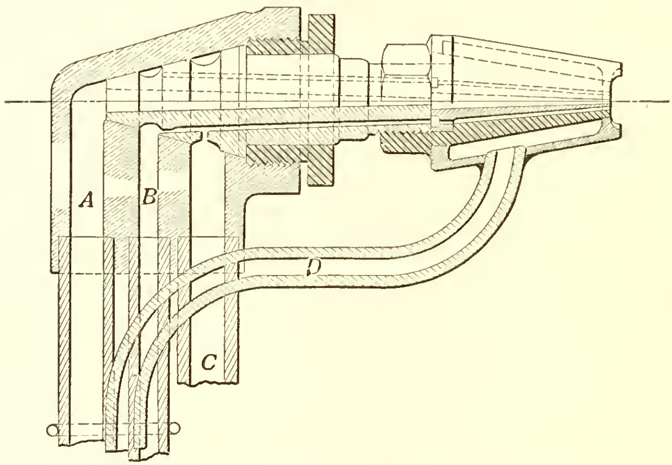


FIG. 63.—Underwater Cutting Torch. *A* cutting oxygen at 65 lb. pressure; *B*, preheating oxygen; *C*, acetylene 24 lb. pressure; *D*, compressed air at 100 lb. pressure.

Davis-Bournonville cutting torch as shown in Fig. 63. This hood is pressed against the metal to be cut, and air at 100 lb. pressure forces back the water and protects the flame. An electrical device is used to light the torch under water.

In one case a cut was made 22 ft. under water by a diver, who cut out a piece 19 in. in circumference in ½ in. ship plate and rose to the surface in 6 min. Six in. per min. was the rate cut on plate 1 in. thick. It is claimed that this torch will cut down to 200 ft. under water.

CHAPTER VII

GAS-PRESSURE REGULATORS AND WORKING ASSEMBLIES

Since the gas pressure required in a welding or cutting torch is normally considerably less than that of a generator or storage cylinder, some form of pressure reducer or regulator must be used between a torch and the source of gas supply. The regulator used must not only reduce the pressures to working amounts, but must keep the gases supplied to the torch at as constant a pressure as possible regardless of the variation in the pressures at the sources of supply. This will be understood when it is shown that, for example, oxygen at 1800 and acetylene at 225 lb. pressure per sq.in., taken from cylinders, must be mixed in a Davis-Bournonville positive-pressure torch at approximate pressures of 14 and 6 lb. respectively, when welding steel plate $\frac{1}{2}$ in. thick. The pressure in the cylinders will constantly decrease as the gases are used, but in order to keep a correct neutral welding flame the gases must be supplied to the mixing chamber of the torch at the approximate pressures of 14 and 6 lb., and keep close enough to these figures for long periods of time to produce the desired flame without continual adjusting of the valves. The required working pressures are determined by the thickness of the metal being operated upon, the make of torch, and the size of tip being used, as tables already given indicate, but the principle remains the same in any case.

Oxweld Oxygen Regulators and Gages.—The gas-pressure regulators used on welding and cutting apparatus are practically all made on the same general principle and vary only in minor details of construction. An Oxweld oxygen regulator shown in Fig. 64 will serve to illustrate the construction in general. The principal parts of a regulator of this kind are the body proper, regulating or shut-off valve, diaphragm, pressure-adjusting spring and pressure-indicating gages. As a general rule all regulators have two pressure-indicating gages, one on the intake or high-pressure line, and one on the outlet, or low-pressure line. The gage, however, on the low-pressure acetylene line is sometimes omitted when using a low-pressure, or injector, torch on account of the low pressure at which the acetylene is used.

In the illustration given, a dust or protecting plug is shown screwed into the connecting nut on the intake tube. This is

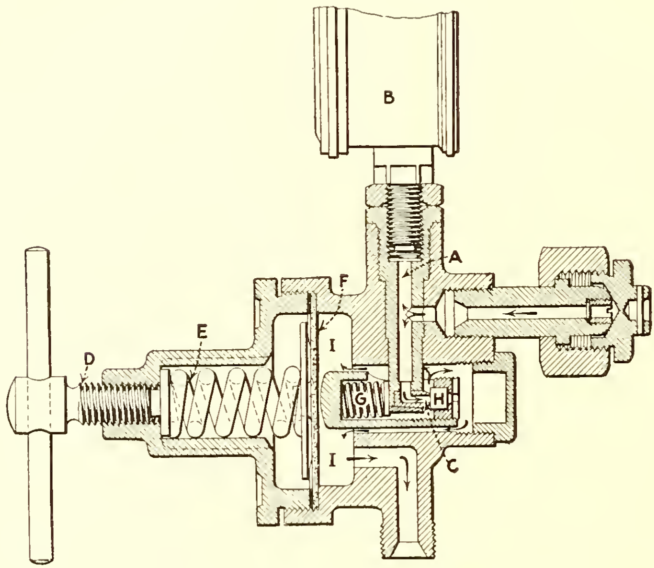


Fig. 64.—Details of Oxweld Oxygen-Pressure Regulator.

of course removed when attaching the regulator to the supply pipe or valve. The arrows indicate the flow of the gas when free to move from the intake to the outlet. Following these arrows it will be seen the gas enters the intake and flows into the vertical passage *A* where it goes upward to the high-pressure gage *B*, which indicates the pressure of the supply line. The gas also flows downward in the same passage until it reaches the monel-metal nozzle of the regulating valve at *C*. If the screw *D* is turned to the left far enough to prevent spring *E* from forcing the diaphragm *F* inward against the sliding sleeve, then spring *G* will keep the seat *H* solidly against the nozzle *C* and no gas will enter the body of the regulator beyond the passage *A*. However, if the screw *D* has been run inward far enough to put a tension on spring *E* the diaphragm *F* will be forced inward and the regulating valve will be held open. Gas will then flow into the diaphragm chamber *I* until the pressure of the gas against the diaphragm overcomes the pressure of spring *E*. This allows spring *G* to close the regulator valve and stop the flow of gas. The flow is not usually actually stopped when the torch is in use, since the flow of gas and the pressure of the spring *E* will be so balanced as to allow just enough gas to enter to keep the pressure practically constant in the outlet line. The farther the screw *D* is run in the more tension is put on the spring *E* and the diaphragm *F*, and consequently the higher will be the gas pressure in the outlet line to the torch. From this it will be seen that any desired pressure within the capacity of the regulator can be obtained, and maintained, in the outlet to the torch by simply adjusting the screw *D*. The diaphragm used on a regulator of this kind may be made of reinforced sheet rubber, phosphor bronze or other composition metal that will not corrode or break easily.

The regulators used for other gases differ but little from those used for acetylene or oxygen, and often the same regulators may be used provided the pressures required are within the range of the regulator in question. An oxygen regulator for cutting work should be built heavier and deliver a larger amount of gas than one used for welding on account of the higher pressure required and greater gas consumption. In using acetylene from a pressure generator it is good practice to have an acetylene line regulator as well as one for each operator's torch line.

The Oxweld oxygen gages used when welding are made to register from 0 to 2700 lb. per sq.in. on the high pressure side and from 0 to 60 lb. per sq.in. on the low-pressure side, as shown in Fig. 65. It will be seen, by examination, that the outer scale on the high-pressure gage shows the pressure in pounds and the inner scale indicates the percentage of gas in the cylinder. That is, for example, if the gage hand points to 600 lb. there would be approximately 35 cu.ft. of oxygen left in the cylinder, providing a 100-cu.ft. cylinder was being used.

If it was a 200-cu.ft. cylinder the amount left would be approximately 70 cu.ft. As has been pointed out elsewhere, these figures cannot be taken as showing the exact amount of gas in the cylinder except under certain conditions, but they are sufficiently accurate for all ordinary purposes.

For cutting purposes the Oxweld oxygen regulator shown in Fig. 66, is fitted with the same gage on the high-pressure

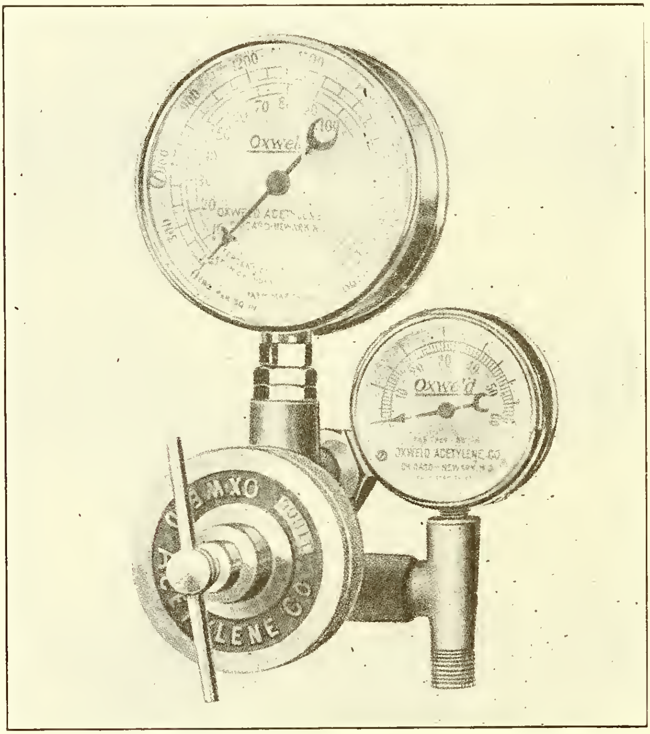


Fig. 65.—Oxweld Oxygen Welding Regulator.

side as for welding, but on the low-pressure side the gage registers up to 200 lb. per sq.in. Their acetylene regulator is only supplied with a 350-lb. gage on the high-pressure side, as shown in Fig. 67. This is because of the fact that the Oxweld torches use acetylene at about 1-lb. pressure at all times. However, if required, two gages may be used as in all other makes.

Other Regulators and Gages.—A Davis-Bournonville oxygen regulator with gages is shown in Fig. 68. This indicates from 0 to 3000 lb. per sq.in. on the high-pressure side and up to 400 lb. on the low-pressure side. On the dial of the high-pressure gage are three rows of figures. The outer row shows the pressure per sq.in.; the middle row, the cubic feet of contents for both 100- and 200-ft. cylinders; the inner row indicates the cubic feet of contents for 250-cu.ft. cylinders at

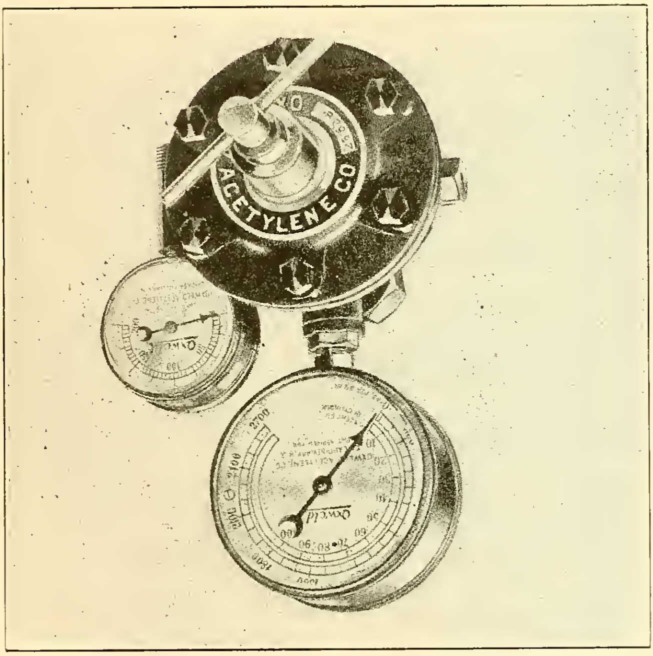


FIG. 66.—Oxweld Oxygen Cutting Regulator.

various pressures. Details of a regulator used for acetylene are shown in Fig. 69. This is practically the same in construction as the oxygen regulator. The numbers shown are list numbers of the parts, and are very convenient for ordering broken or damaged parts at any time. The regulator acetylene gages register up to 400 lb. on the high-pressure side and up to 300 lb. on the low-pressure side.

An oxygen regulator made by the General Welding and Equipment Co., attached to a cylinder is shown in Fig. 70.

At the right and almost opposite from where the regulator is attached, is a projection which is a fusible blow-off plug required on all cylinders by the Interstate Commerce Commission, to provide for the escape of the gas in case the cylinder should be overheated and the pressure become so great as to be liable to cause an explosion. This illustration clearly shows the kind of valve that is used on an oxygen cylinder. It is completely covered with a metal cap screwed onto the threads

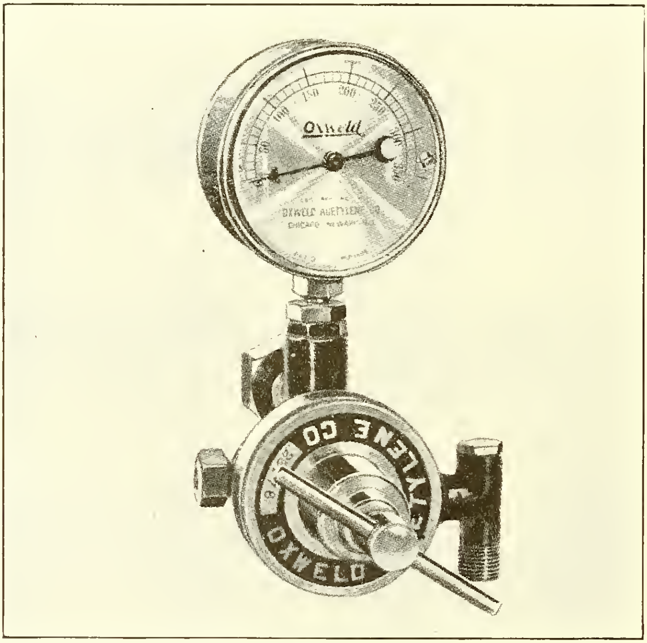


FIG. 67.—Oxweld Acetylene Regulator.

shown at the top of the cylinder. The cap protects the valve and prevents it being broken off or damaged when the cylinder is handled or shipped. In using gas cylinders under working conditions it is advisable to have them placed on a portable truck made for the purpose, or else fastened in some way so that they cannot be tipped over. This will often prevent needless damage to the apparatus and sometimes avoid serious accidents. It should always be kept in mind that gases under from 225- to 1800-lb. pressure per square inch are not to be trifled with.

Tank and Hose Colors.—Oxygen cylinders of different concerns do not have a uniform color, but are usually painted gray and green, red, yellow or dark-green. Acetylene cylinders are generally painted black and have a plate on them giving

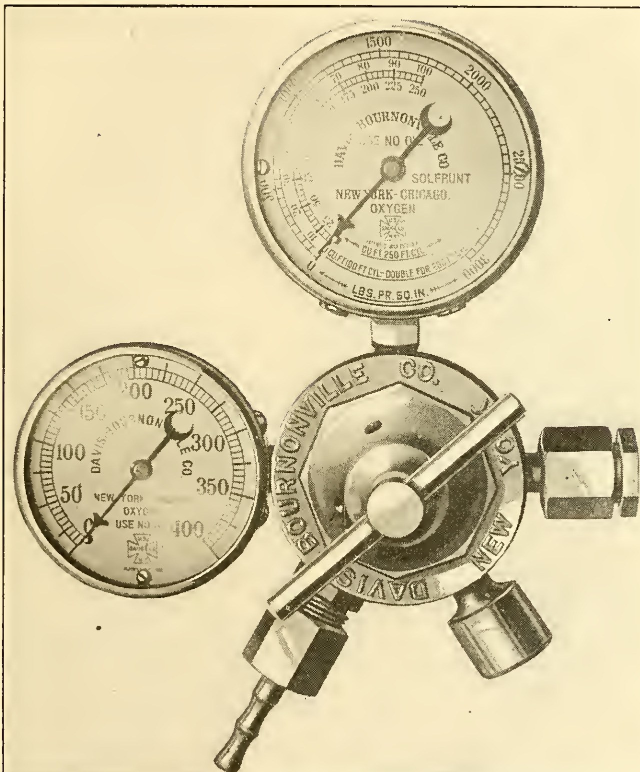


FIG. 68.—Davis-Bournonville Oxygen Regulator.

the quantity of gas the tank contains. Practice also varies as to the color of hose used to connect to the torches. Common colors are black hose for acetylene and red hose for oxygen, although sometimes oxygen hose is black and the acetylene red. In making all hose or valve connections, they must be carefully blown out to remove dust or any foreign substance. This is especially important on new hose which is almost sure to contain considerable bloom left from the vulcanizing. In addition to their specific color, acetylene cylinder valves are often threaded left hand, as a safeguard against making the wrong connections.

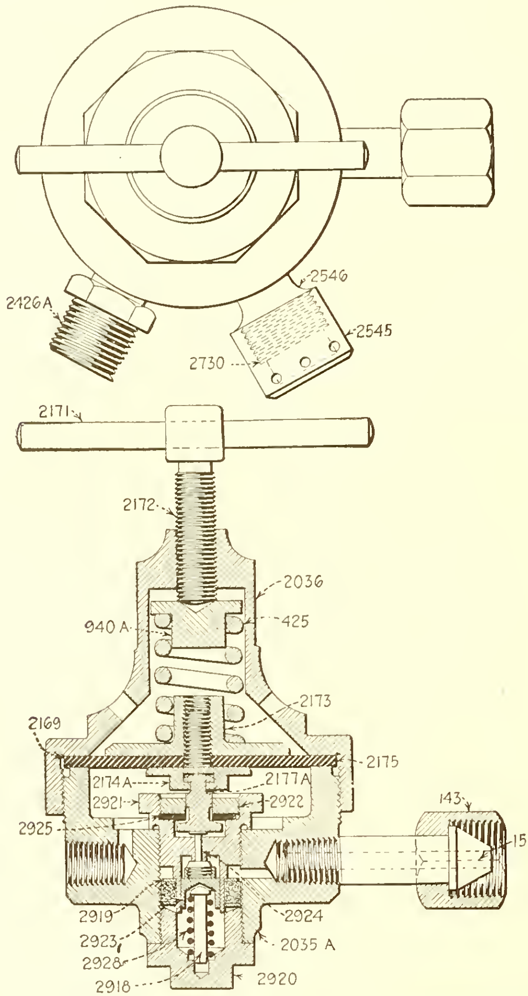


FIG. 69.—Details of Davis-Bournonville Acetylene-Pressure Regulator.

In making oxygen connections it must be remembered that under no circumstances should oil or grease be used on the oxygen regulator or cylinder valve. This is highly important as oxygen under pressure coming in contact with oil or grease causes spontaneous combustion which might easily result in

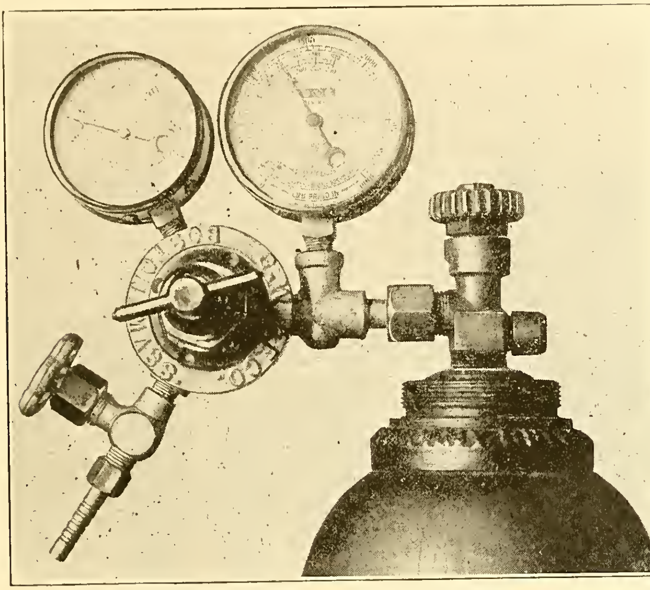


Fig. 70.—Regulator Attached to a Gas-Cylinder Valve.

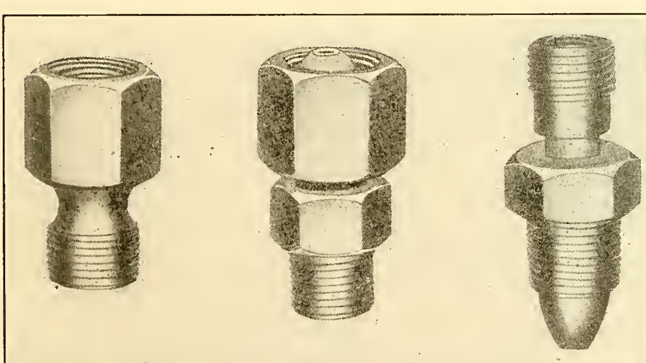


Fig. 71.—Regulator and Cylinder-Connection Adapters

a serious accident. If a lubricant of any kind is needed a little glycerine may be used.

Regulator Adapters.—No make of regulator is so made as to be regularly interchangeable with all makes of gas cylinders, since the sizes and threads used on different makes of cylinder connections vary considerably. For this reason adapters must be used in many cases. Some of these are shown in Fig. 71. Care should therefore be taken to make sure that the regulator will fit the cylinder connections properly, or that the right adapter is used. If a regulator connection or an adapter does not start readily, it should not be forced as it is probably the wrong diameter or the thread may be of the opposite kind—that is right- or left-hand. Also be sure that an adapter with a round or conical seat is not used on a flat seat, nor a round seat on a conical one or one not made for it. Adapters are made of soft brass and careless handling will cause a leaky joint. In ordering adapters the make of regulator used should be specifically stated, and also the make of cylinder on which it is to be used, as well as whether it is for oxygen, acetylene, hydrogen or other gas.

Connecting Up and Lighting the Torch.—In order to make perfectly clear to the reader how to connect up a welding apparatus for the first time, an Imperial welding outfit is shown in Fig. 72. First remove the protecting cap from the oxygen cylinder, and then open valve *A* very slightly. This is to blow out any dust and to insure the free working of the valve after the regulator is attached, which otherwise might be injured by the sudden rush of gas into it. In doing this, stand on the side opposite from the opening so that the gas will blow *away* from you. Always keep this in mind when blowing out the valve on *any* cylinder. Now take the regulator and turn the handle *B* to the left until it turns freely, so as to be clear of the diaphragm. Next make sure the connection at *C* is clean and free from dirt and fits properly or has the right adapter, then screw it up using judgment with the wrench so as not to break anything. With the valve at *D* closed, *slowly* open the valve *A as far as it will go,* using some force with the hand to insure that it is really backed up against the gland solidly. This is to aid in preventing the high-pressure oxygen from escaping around the valve stem. When the valve is fully opened, the gage *E* will indicate the cylinder pressure which on a new one will be close to 1800 lb. Now put on the oxygen hose at *F* and then turn the handle B to the right until about 5 lb. are registered on gage G. Then open valve to D so as to blow any dirt or bloom out of the hose. The valve D is then closed and the hose connected to the torch at H. The valve I on the torch may now be closed, the valve D opened, and the handle B screwed in until the gage G registers the proper pressure for the proposed welding job,

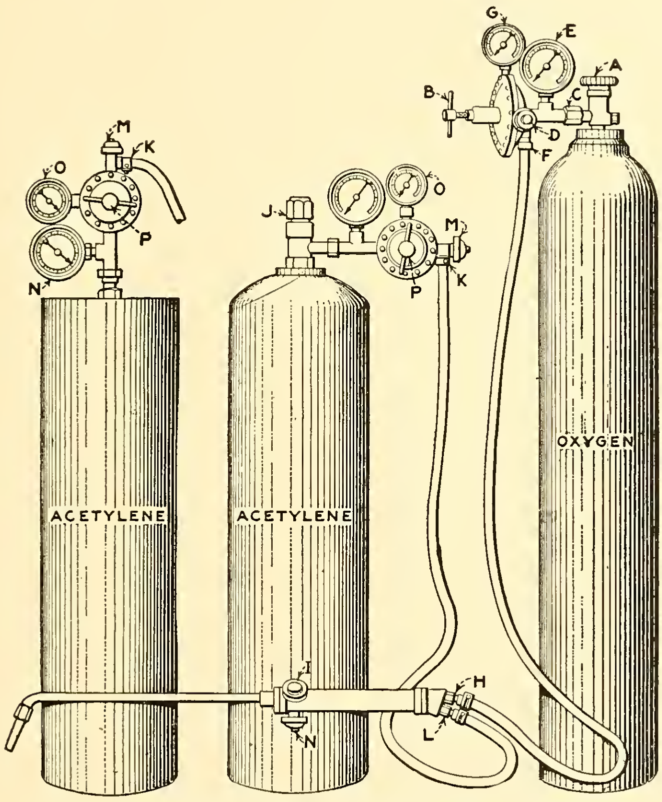


FIG. 72.—Imperial Welding Outfit Connected to Tanks.

as indicated in the pressure table for the make of torch being used. The various connections should then be carefully gone over with soapy water to test for leaks. Never use a flame on the oxygen or any other gas tank even though oxygen alone is not inflammable. Assuming that the proper tip has been placed in the torch for the thickness of metal to be welded, the torch valve I may now be opened fully and the handle screwed in until the gage *G* registers about 2 lb. over the pressure given in the table. This is to allow for the variation in cylinder pressure as the gas is used. The torch valve *I* is next closed, and it is also well to close the valve *D* as a safeguard before attaching the acetylene hose.

The acetylene regulator and tank are now connected up in exactly the same way, except that the acetylene tank valve *J, must be only opened one full turn.* (On one make of cylinder the directions say two turns, so the operator should read the directions on the tank carefully.) The hose is connected at *K* and blown out to remove any dirt, care being taken that no flame is near. It is then connected to the torch at *L*, and tests are made for leaks as before with the valve *M* open and the torch valve *N* closed. The torch valve *N* is next slightly opened and the issuing gas lighted. The valve is then fully opened, and if the gage *O* shows any appreciable drop, the handle *P* should be turned until the gage registers about 2 lb. above the amount shown by the table. The resulting flame from the burning acetylene will be long, white, smoky, and of comparatively low temperature. The torch valve *N* may then be manipulated until the pressure blows the flame from $^1/_{16}$ to $^1/_4$ in. away from the tip, the distance depending on the size of the tip being used. This can only be judged properly by experience. The oxygen may now be turned on slowly. The flame will gradually reduce in size, the outer end or envelope becoming less luminous and the part near the torch tip, known as the cone, assuming a clear outline without any ragged edges. When this is obtained, turn off the oxygen slowly until a shadowy point shows from the cone. Then with extreme care turn on the oxygen again until this shadowy point just disappears. This is the so-called neutral flame, and is neither oxidizing nor carbonizing.

From time to time, while at work, the operator should test the flame as just outlined, as a slight excess of oxygen pressure will not readily show in the flame and can only be detected by this method. It will be found in practice, as a rule after the pressures have been set on the gages, that all regulation necessary for the smaller sizes of tips may be made with the torch valve, but that on the regular sizes it is often advisable to readjust at the regulators. It will be well to repeat here, for the benefit of the beginner, that all indicated table pressures are only approximate and good only for the make of torch mentioned in connection with them.

Characteristics of the Oxy-Acetylene Welding Flame.—The chart shown in Fig. 73 will serve to illustrate the looks of the oxy-acetylene flame as far as it is possible to do on paper: *A* shows acetylene turned on with sufficient pressure, so that it blows away from the tip. This space depends upon the size of tip being used. *B* shows oxygen partly turned on, united with the acetylene. The flame has begun to assume two different shapes and two different colors. The center

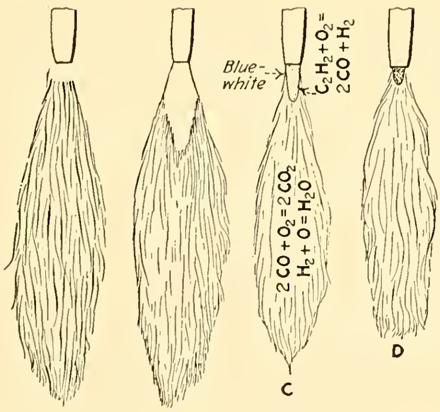


FIG. 73.—Characteristics of the Oxy-Acetylene Welding Flame.

flame is white and is shaped somewhat like a rosebud. Not enough oxygen has yet been given the acetylene and the flame is called carbonizing. Such a flame will leave the metal brittle and hard. *C* is the neutral welding flame. The rosebud cone of the upper figure has become blunt, with no ragged edges and of a beautiful blue-white color. *D* is an oxidizing flame—ruinous to welding. This is obtained by turning on too much oxygen and the cone has become shorter, of a darker, dirtier blue, and is more pointed. This view is exaggerated. The utmost care is necessary to guard against this flame. Even a slight excess of oxygen is detrimental, as it will "burn" the metal.

To stop work temporarily, first close the oxygen valve in the torch and then the acetylene valve. To stop work permanently, first close the torch valves in the order just given, then screw back both regulator handles until they are free of the diaphragms. Then shut off the tank valves tightly.

In case of a flashback, always close the oxygen valve instantly, then the acetylene valve, after which the torch head may be cooled in a bucket of water. It should always be kept in mind *never to turn on the gas at the cylinder with the regulating screw tight, as this puts spring tension on the diaphragm* and allows the gas from the cylinder to enter the body of the regulator very suddenly (because the plunger of the valve is away from the seat) and as the sudden pressure strikes the diaphragm, the plunger is thrown violently against the seat, often causing the seat to become cracked or broken.

With the motor of an automobile racing, you wouldn't throw the gears in mesh for high speed direct from neutral and attempt to start away from the curb—not if you wanted to keep your automobile very long—yet turning on the oxygen with the spring tension on the regulator has about the same effect on the regulator.

Bear in mind that the regulator is a steadying device—that the diaphragm is the balance between the high pressure of the cylinder gas and the spring tension and that at all times the movement of this diaphragm should be slow—never violent.

The low-pressure gage is a positive index of regulator trouble. If you are operating, say at 15 lb., and after shutting off the valve on the torch, the hand on the dial keeps moving to 25 or 30 or 40 lb. without stopping, it means that the seat is damaged—that the high pressure of the cylinder is leaking past the plunger of the valve and the regulator should be immediately sent back to the factory for repairs. Only by violating some of the rules previously given would you be likely to damage this seat; but once damaged, it should be immediately repaired.

It will be noticed that two acetylene tanks are shown in Fig. 72. These represent the two types in common use. The one in the middle is the type furnished by both the Air Reduction Sales Co. and the Commercial Acetylene Co., while the tank at the left is furnished by the Prest-O-Lite Co. In the first named the regulator stands out at right angles, and in the other it stands up as shown. The valve in the Prest-O-Lite cylinder differs considerably from the others as will be seen in Fig. 74. In this illustration the valve is shown at *A,* the valve wrench at *B,* the packing nut of the valve at *C,* and the union nut by which the regulator is attached, at *D. E* is the high-pressure gage, F the low-pressure gage, *G,* the regulator, *H* the pressure-adjusting handle, *I* the outlet and *J* the hose nipple.

Lighting the Oxweld Low-Pressure Torch.—The directions given by the Oxweld company for the lighting of their low-pressure or injector torches, differ slightly from the foregoing,

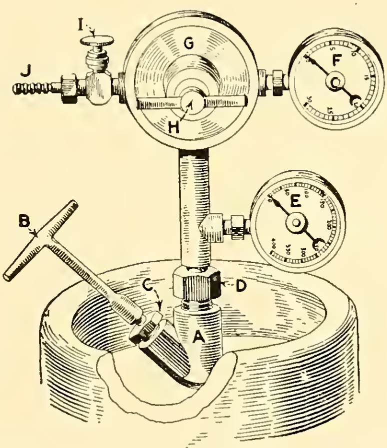


FIG. 74.—Prest-O-Lite Acetylene-Regulator Assembly.

so they will be quoted here, starting from where the gases have been turned into the high-pressure sides of the regulators, which is the same as already outlined:

First, connect the oxygen hose from the oxygen regulator to the hose connection on the torch marked oxygen. Likewise connect the acetylene hose to the torch valve marked acetylene. Then select the proper welding head or tip that is to be used according to the chart or table furnished, and screw it carefully into the torch. Turn on the oxygen by means of the handscrew of the oxygen regulator until the pressure on the small gage is as given on the chart. Be sure that when this is done the oxygen valve on the torch is open. Then close this valve. Open the acetylene valve on the torch. Then turn the handscrew on the acetylene regulator to the right until acetylene is passing through the torch. Then close the acetylene valve on the torch.

The apparatus is now ready for use, and the gases are further regulated when necessary by adjusting the valves on the torch itself. Open the acetylene valve entirely. Open the oxygen valve slightly. Then light the gases. After lighting the gases, open the oxygen valve wide; adjust the flame by turning the acetylene valve to the right until a neutral flame is produced.

When the job is finished and you want to shut off the torch for a short time, release or turn the handscrew on both oxygen and acetylene regulators to the left until the flame on the torch goes out. Then close the torch valves. When work is completed for the day and the apparatus is to be put away, first close the acetylene valve, then the oxygen valve of the torch. Then turn off the valves on *both* cylinders. Then open the valves on the torches until all the gas in the regulators and hose passes out of the torch into the air. Then turn the handscrew of both regulators to the left until loose. Then disconnect the oxygen and acetylene regulators from the cylinders. Each regulator has a dust plug which is to be put on its cylinder connection during all the time the regulators are not connected to the cylinders.

Place the regulators and torches with wrenches, goggles, heads, and tips in their proper place so that they will be safe and protected from dust, dirt, and rough handling. Roll up the hose and put it in the case or tool box where it belongs.

Chemistry of the Oxy-Acetylene Flame.—According to the Prest-O-Lite company, the chemistry of the oxy-acetylene flame is as follows: Acetylene (C_2H_2) is composed of carbon (C) and hydrogen (H). On combustion, the carbon combines with oxygen to form carbon dioxide (CO_2) and the hydrogen combines with oxygen to form water vapor (H_2O). This takes place in the following manner:

When the gases issue from the torch into the welding flame, the acetylene immediately dissociates; in other words, it *splits up* into carbon and hydrogen which in combination with oxygen form respectively carbon dioxide and water vapor. In consequence of the high flame temperature (6300 deg. F.) the water vapor formed by this primary combustion is immediately dissociated into hydrogen and oxygen. The oxygen assists in the burning of the carbon while the hydrogen (which can only combine with oxygen at a temperature below 4000 deg. F.) passes away from the high-temperature zone and combines with the oxygen of the atmosphere at the outer blue part of

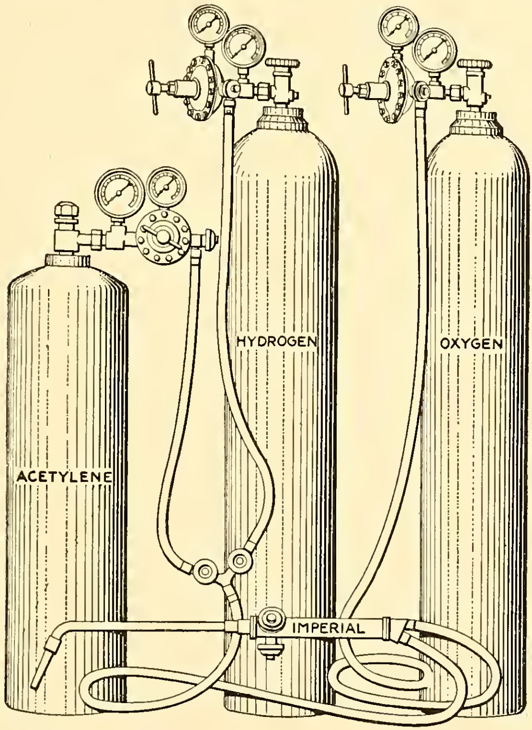


FIG. 75.—Imperial Three-Way Gas Outfit.

the flame, where the temperature is sufficiently low to permit it. The result of this is that the inner or welding cone of the flame is protected by a shield of free hydrogen which prevents loss of heat and also tends to protect the weld from oxidation. The temperature of the oxy-acetylene flame is approximately 6300 deg. F., at the hottest part of the flame, which is the tip of the inner white cone. The effect of this tremendous heat at the point of treatment is to bring the metal very rapidly to a molten state so that it flows together and mixes thoroughly with the proper quantity of metal added by the operator.

The molten mass thus formed does not merely cement two pieces of metal together—it *fuses* them into one uniform mass.

Characteristics of Other Gas Flames.—The way an Imperial three-way outfit is connected up is shown in Fig. 75. The procedure is along the same lines as outlined for the oxy-acetylene work. This combination of oxygen, acetylene and hydrogen gives a more visible flame and a sharper cone than oxy-hydrogen alone does. Only a small percentage of acetylene is necessary to give the sharper cone but the flame retains the clearness, beauty and good qualities of the oxy-hydrogen flame. The percentage of acetylene may be varied according to the thickness and character of the metal being welded, so that the degree of heat and amount of carbon can thereby be regulated to meet different conditions. The approximate pressures to be used for the three gases for average work, will be found in a previously given table. The combination will produce a heat of about 5000 deg. F.

The oxy-hydrogen flame will produce a much softer weld than oxy-acetylene if properly used, but its lower heat and the fact that the cone is not concentrated in a sharp needle point, which allows the heat to radiate more, are drawbacks when heavy welding is attempted. The low visibility of the oxy-hydrogen flame also makes it difficult to regulate properly, and an operator requires considerable experience before he can become proficient in its use. As has been already mentioned, however, its long flame makes it very desirable to use for the preheating flame in a cutting torch, especially on heavy, thick work. In welding with the oxy-hydrogen flame, the torch has to be held farther away from the work than with the oxy-acetylene torch on account of the longer and less concentrated flame. When a black spot appears in the weld it shows that the torch is being held too close.

The Oxy-Hydrogen Flame.—The characteristics of the oxy-hydrogen flame are shown in Fig. 76. In this illustration, which is as clear as a flame can be represented on paper, the different flames are outlined as follows: *E* shows the hydrogen turned on with sufficient pressure so that it blows away from the end of the tip. The distance will vary from about $^1/_{16}$ to $^1/_4$ in. according to the size of tip and pressures used. *F* shows the oxygen turned on. A narrow, light-blue streak appears in the center of the hydrogen mantle. This is the desired neutral flame. *G* is an oxidizing flame that will burn the metal. The oxygen valve should be gradually closed until the excess of oxygen disappears.

Where hydrogen and compressed air are used as is done in preheating work, light welding, or lead burning, the flame closely resembles that of the oxy-hydrogen flame. The appear-

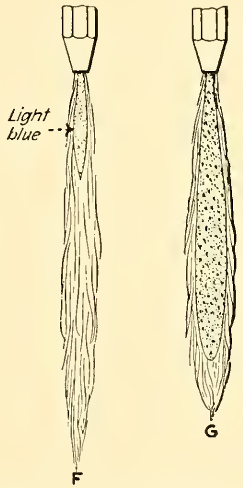


FIG. 76.—Characteristics of the Oxy-Hydrogen Flame.

ance of the hydrogen-air flame is indicated in Fig. 77. *H* shows the hydrogen turned on with pressure enough to blow the flame away from the tip, the distance being about the same as already given. *I* shows the compressed air turned on and a dark streak of mixed air and hydrogen appears in the center. This is the neutral flame. *J* is the oxidizing flame.

In general the air pressure used for this flame is close to that where oxygen is used.

The Oxy-Illuminating Gas Flame.—The flame produced by mixing oxygen and coal gas, or natural gas, is suitable only for lead burning, preheating, very light steel welding, light cast-iron welding, or the welding of light brass or aluminum.

The characteristics are shown in Fig. 78. *K* shows the gas turned on full force enough to slightly blow the yellow flame

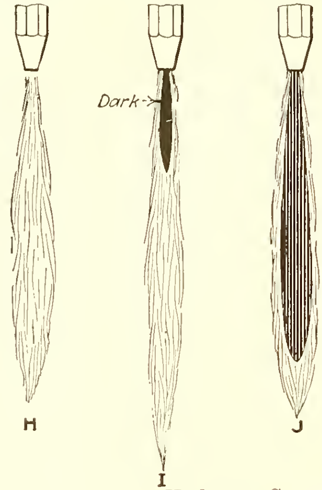


FIG. 77.—Characteristics of the Hydrogen-Compressed-Air Flame.

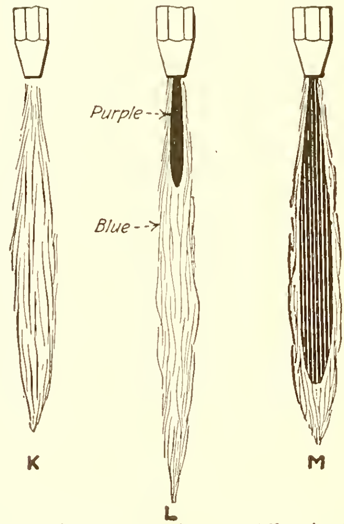


FIG. 78.—Characteristics of the Oxygen Illuminating Gas Flame.

away from the tip. *L* is the neutral flame produced by turning on the oxygen. The cone is narrow and about $\frac{1}{2}$ in. long, of a beautiful purple color in a pure-blue outer mantle. *M* shows too much oxygen. The cone has turned a reddish color. The oxygen must be decreased until the sharp purple-colored cone appears. In using oxygen and illuminating gas, a water seal should be used on the gas line to assist in purifying the gas and to prevent the entrance of any flame, or oxygen which might form an explosive mixture.

Where acetylene and compressed air are used, as is sometimes done for certain preheating or welding jobs, the flame characteristics closely resemble the oxy-acetylene flame.

In order to obtain the best results, special tips should be used in the torch for the different gas combinations described. These can usually be promptly supplied by the makers of any of the torches on the market.

CHAPTER VIII

GAS-TORCH WELDING AND CUTTING OUTFITS

Cutting torches are lighted in the same way as are the welding torches. In most cases, however, the oxygen pressure to the preheating flame has to be several pounds higher, on account of the drop after the cutting jet is turned on. The apparatus used for cutting is also set up in the same way as for welding, as will be seen from the typical Oxweld cylinder outfit shown in Fig. 79.

Where large amounts of oxygen are used for cutting or welding, it is well to have a centralized source of supply so arranged that the flow of oxygen need not be interrupted at any time, and will be ample for all demands. For this purpose, the Oxweld company has designed the oxygen cylinder manifold shown in Fig. 80. Oxygen from this manifold may be piped anywhere in a plant exactly the same as the acetylene is. It eliminates the enormous amount of handling necessary in supplying full cylinders and removing the empty ones from each individual station. The manifolds are so arranged that each half operates independently, making it possible to provide an uninterrupted supply of oxygen. If desired, both halves may be operated in unison. These manifolds are made in four sizes to accommodate, 6, 10, 20 and 30 cylinders respectively. Each manifold will handle cylinders of either 100- or 200-cu.ft. capacity without any additional change or adjustment. They have two constant pressure regulators, one of which is for relief service.

Acetylene cylinder couplers or manifolds are used for the same reason as are those for oxygen. A number of Prest-O-Lite acetylene cylinders coupled together is shown in Fig. 81. These are valuable where large-sized torch tips are used more or less continuously, since the capacity of the cylinders supplying acetylene should be at least seven times the hourly consumption. Where the hourly requirements are from 61 to 75 cu.ft. of acetylene, 5-WC or 2-WK size cylinders should be used.

Complete Working Outfits.—A welding or cutting outfit may consist of the bare essentials, or be so complete as to

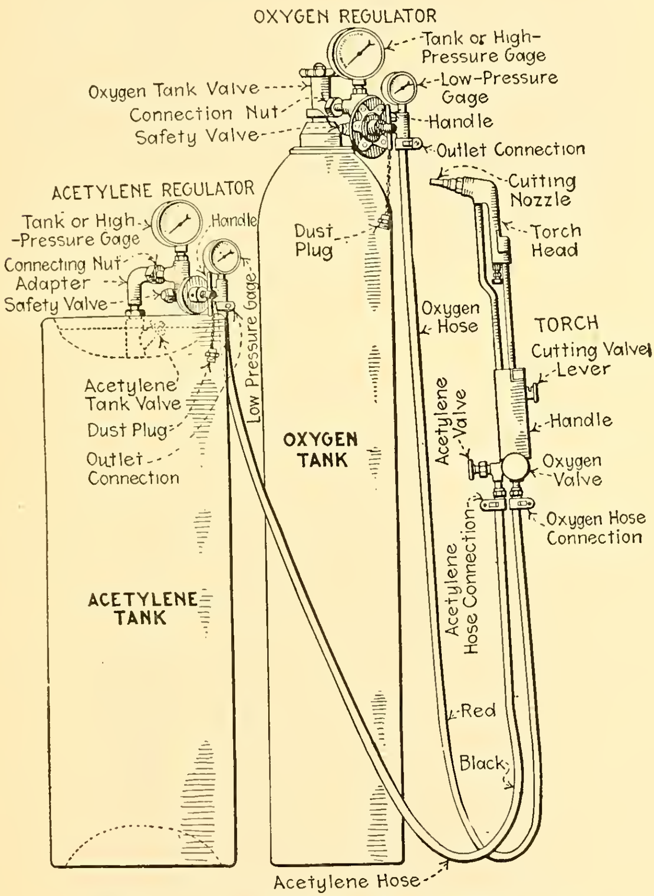


FIG. 79.—Typical Oxy-Acetylene Cutting Unit.

include everything that will be needed to care for any job that will come along. The outfits may also be of either the stationary or the portable type, or a combination of the two. If of the stationary type, there will naturally be included many things such as holding jigs and fixtures which do not

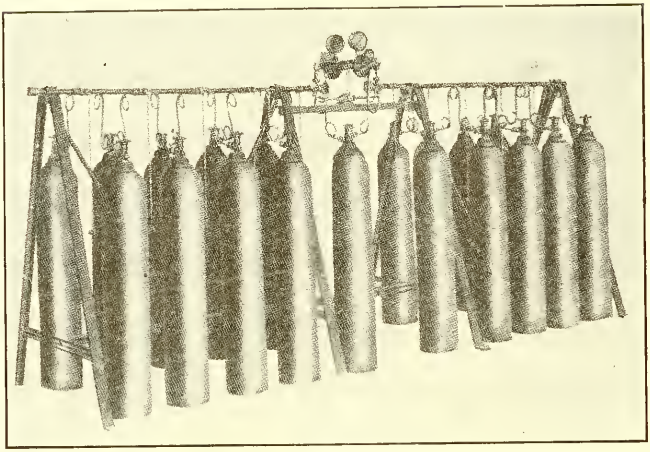


FIG. 80.—Oxweld Oxygen-Cylinder Manifolds.

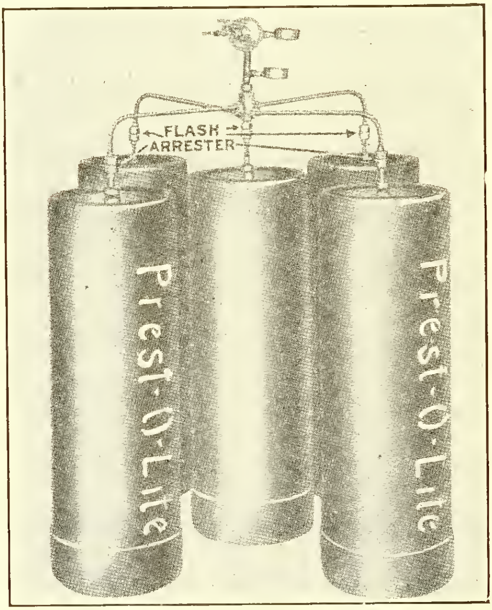


FIG. 81.—Prest-O-Lite Acetylene-Cylinder Manifolds.

ordinarily belong to the strictly portable type. Two typical lists of parts and material for the ordinary run of work, where gas cylinders are used, are here given. These lists are taken from the catalogue of the K-G Welding and Cutting Co., New York.

Oxy-Acetylene Cutting Unit

1 cutting torch, standard size, with four interchangeable tips of graduated sizes.
1 high-pressure oxygen regulator, with 3000-lb. gage for cylinder pressure, 300-lb. gage for working pressure and one reducing valve with connection for hose coupling and needle valve.
1 acetylene-pressure regulator with 400-lb. gage for cylinder pressure, 60-lb. gage for working pressure and one reducing valve with connection for hose coupling and needle valve.
25 ft. high-pressure, copper-covered oxygen hose.
25 ft. steel-covered gas hose.
1 pair colored goggles for operator.
1 pair fireproof gloves.
2 wrenches and flint lighter, instructions, etc.
1 leather instruction and memorandum book.

Oxy-Acetylene Welding Unit

1 welding torch, standard size, complete with eight interchangeable tips of graduated sizes.
1 low-pressure oxygen regulator, with 3000-lb. gage for cylinder pressure, 60-lb. gage for working pressure and one reducing valve with connection for hose coupling and needle valve.
1 acetylene-pressure regulator with 400-lb. gage for cylinder pressure, 60-lb. gage for working pressure, and one reducing valve with connection for hose coupling and needle valve.
25 ft. red corrugated-rubber oxygen hose.
25 ft. black corrugated-rubber gas hose.
1 pair colored goggles for operator.
1 pair fireproof gloves.
2 wrenches, 1 flint lighter, instructions, etc.
10 lb. cast-iron rods.
10 lb. Norway iron for welding.
2 lb. aluminum rods.
1 lb. cast-iron flux.
½ lb. aluminum flux.

It, of course, is not necessary for a user to purchase two complete units if his work does not warrant it, as these may be judiciously combined. For instance, the welding unit may be used for either welding or cutting if a cutting torch and a high-pressure oxygen regulator are added. It is very convenient where portable apparatus is used to a considerable extent over an extended territory, to have a suitable carrying case for the smaller parts. This may consist of a chest attached to the cylinder or portable truck, or of a hand case, such as shown in Fig. 82. This case and outfit is sold by the Air Reduction Sales Co., New York, and holds everything necessary for immediate attachment to the cylinders and starting to work.

It has been previously mentioned that it is not advisable

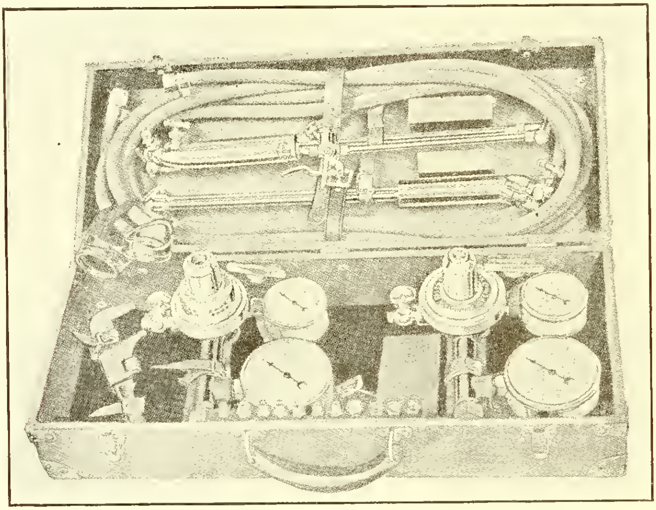


FIG. 82.—Carrying Case for Welding and Cutting Outfit.

to place gas cylinders so that they may be knocked over. If they have to be stood up near the work, it is best to chain them to a post or brace them up in some way. A portable truck is, of course, the best of all where outfit must be moved about. Such a hand truck has already been shown. Practically every firm making gas-torch supplies sells a similar one.

A very important part of any gas-torch outfit is a pair of suitable glasses or goggles. These should not be merely dark glasses, but the lens should be made expressly for work of this kind. Cheap glasses are dear at any price, as the result may be ruined eyesight from the intense glare of the hot metal or from injurious rays. The glasses may be of either the spectacle or the goggle form, but the lens should be the same in either case. Glasses may be obtained from practically any of the firms mentioned in the various descriptions. The goggle form of glasses has the advantage over those of the spectacle type in that they will better protect the eyes from flying or glancing particles of hot metal or sparks. It is well to have the colored lens protected by clear glass. A pair of goggles is shown in Fig. 83. These are of a very satisfactory form. They are light and all parts that come in contact with the skin should be made of fiber, metal, or something that is sanitary and easily sterilized. The guards may be made of aluminum screen or fiber. Never on any account use goggles with guards

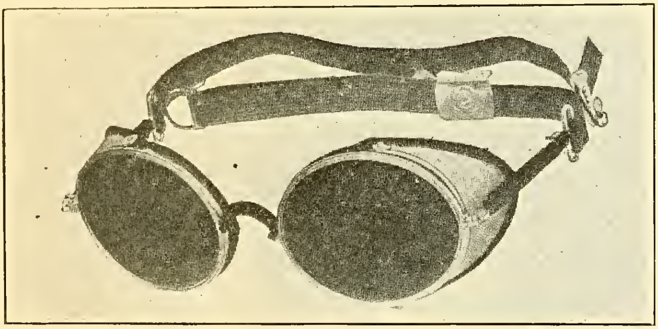


Fig. 83.—Goggles for Gas-Torch Work.

made of celluloid. If the glasses used can be employed for long periods of time without the eyes feeling "dazzled," or if they can be removed without white spots appearing before the eyes, then they are all right. Otherwise get others that are better fitted for the work and your eyes. A darker lens is usually used for welding than for cutting and sometimes it is advisable to use different glasses for different metals. These will enable the operator to see more clearly when the glare is not so intense.

Fire-fighters often need to cut through steel or iron window bars, shutters, steel plates or sheathing, in order to rescue imprisoned persons or to get at a fire advantageously. For this purpose the Davis-Bournonville Co. supplies a very compact apparatus, shown in Fig. 84. The metal case is 6½ in.

wide, 14 in. deep and 50 in. high. It contains a 40-cu.ft. cylinder of acetylene, a 50-cu.ft. cylinder of oxygen, and a complete cutting unit with extra length of hose. Handles on each side of the case provide means for easy carrying by two

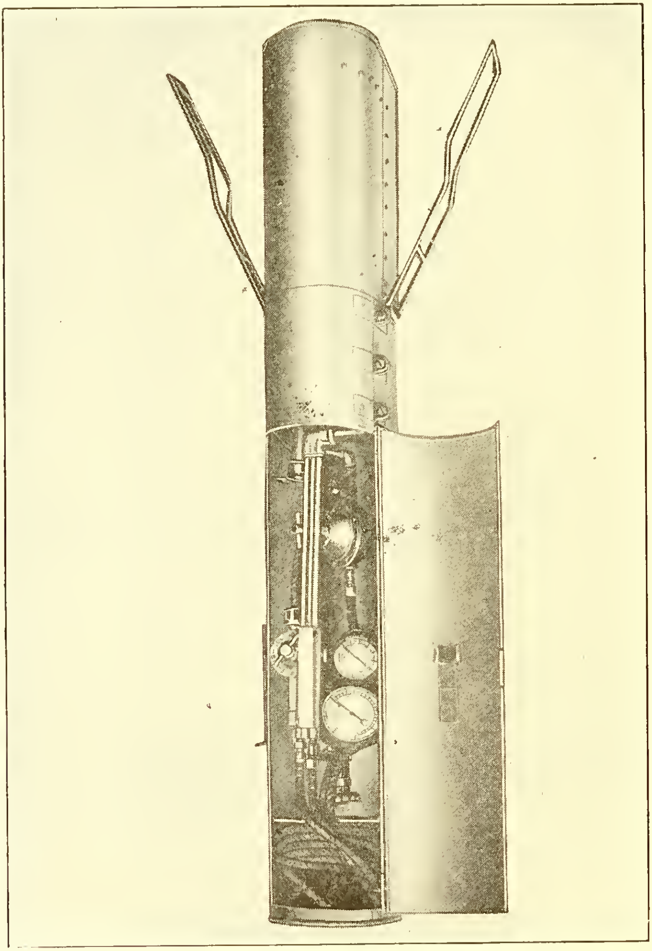


Fig. 84.—Emergency-Cutting Outfit.

men, and these handles placed as shown, when in use, insure stability. The complete outfit weighs 125 lb.

A complete two-station welding and cutting outfit of the stationary type, using an acetylene generator and oxygen

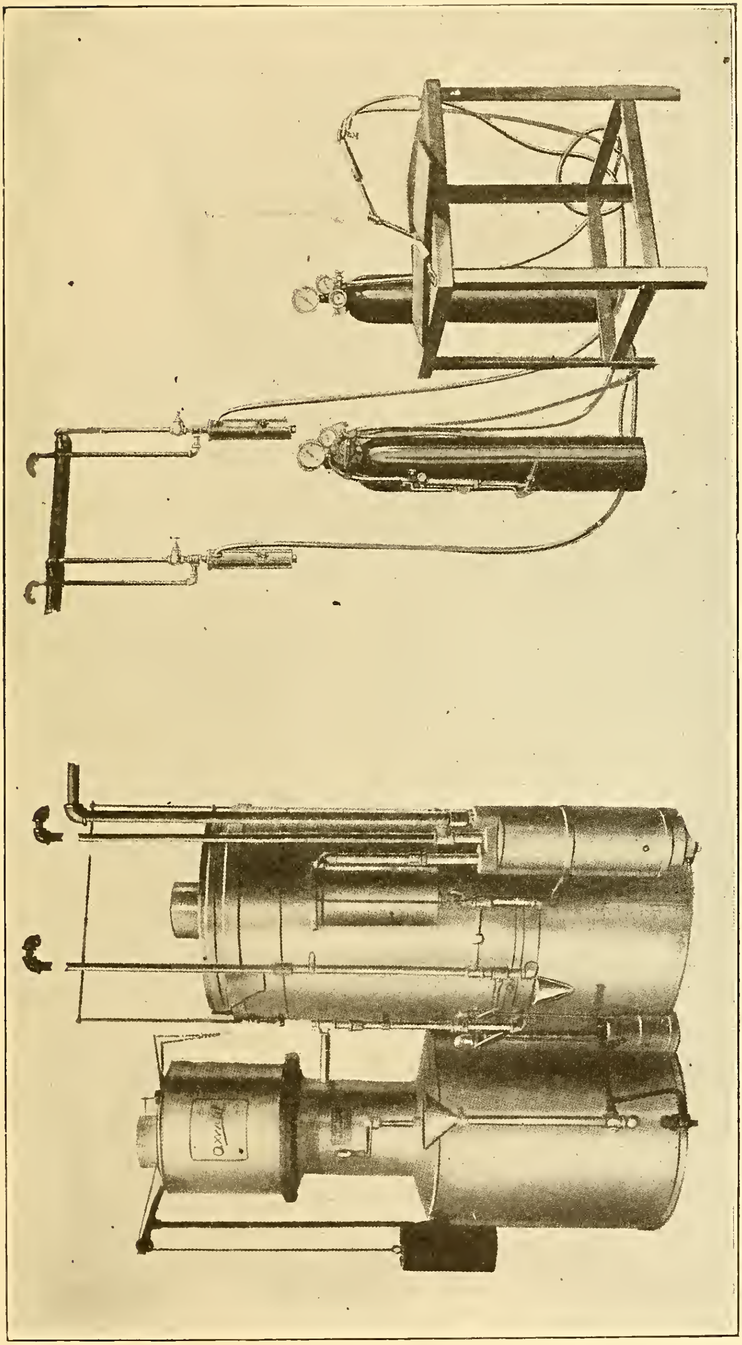


FIG. 85.—Oxweld Acetylene Generator and Oxygen Cylinder Two-Station Outfit Connected for Welding and Cutting Work.

cylinders, is shown in Fig. 85. This can be extended to include any number of individual stations, according to the size of the generator employed. It is advisable to place the acetylene generator in a separate room or building. The oxygen cylinders and regulators are placed within easy reach of the workers.

Back-Pressure Valves.—Hydraulic back-pressure valves

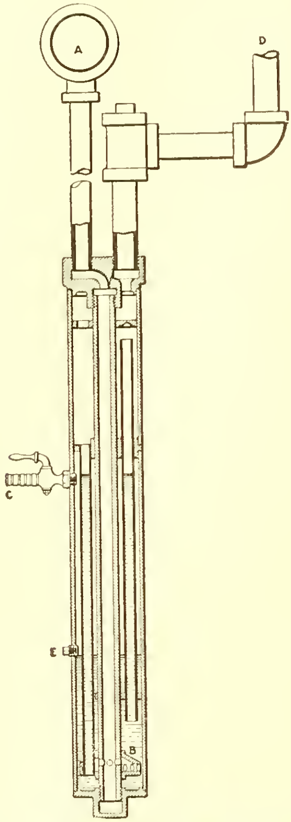


FIG. 86.—Oxweld Low-Pressure Hydraulic Back-Pressure Valve.

should always be connected to the individual acetylene pipes, as shown, to avoid the danger of a flashback or an explosive mixture entering the acetylene line. An Oxweld low-pressure back-pressure valve is shown in Fig. 86. In some quarters it is thought that such a valve is not needed where positive-pressure torches are used, but this is not true, as the danger is always present when the oxygen pressure is greater than that of the acetylene or which, through accident, may become greater. An obstruction in the nozzle of the torch, or clogging of certain passages is apt to force the oxygen into the acetylene line. There are also other conditions which may cause a serious accident. While mechanical valves may help, they are not so reliable as hydraulic valves and should not be used on shop lines. In the valve shown, the acetylene enters at *A* and bubbles out at *B* where it rises to the surface of the water seal, and normally goes out of the hose valve *C*. The depth of the water through which the acetylene bubbles is sufficient to cover the tube leading to the outside air. If there is a backward flow of oxygen, the pressure exerted on the surface of the water lowers its level, causing it to rise in the tube open to the air, and if continued, forces it out of the tube, thus opening a clear passage for the oxygen to the outside air at *D*. The acetylene inlet meanwhile is protected by a seal of water.

To avoid the possibility of blowing the water out of the seal, the valve is so designed that in case of a blow-back the water automatically flows back to the body of the valve, renewing the seal.

The high-pressure valve of this type is provided with a ball check seated under water, which effectually prevents an excess pressure from working backward into the generator. It is also supplied with a relief valve of ample size to carry off any excess pressure which may accumulate in the body of the hydraulic valve.

Both the high-pressure and low-pressure valves should be kept full of water up to the screw plug *E* which is provided to regulate the height of water when filling.

Lead Burning.—Lead burning is practically the same as any other welding work, except that the melting point of lead (620 deg. F.) calls for a much smaller flame. The same outfits intended for lead burning may be used for welding jewelry, small metal parts of various kinds, or for brazing work in some cases. On account of the torch itself being made small and as light as possible, it is customary to have only an oxygen valve on it, the gas and oxygen valves being placed in a "bench block" placed about midway between the torch and the sources of supply. For lead burning alone, it is usually advisable to use some gas combination giving less heat than oxy-acetylene, such as oxy-hydrogen, hydrogen and compressed air, oxygen

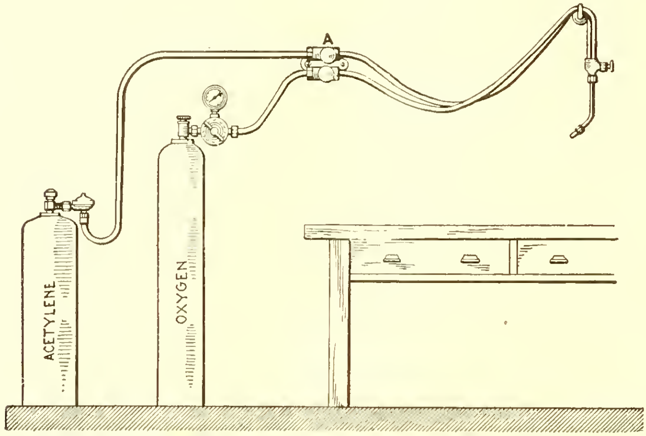


FIG. 87.—Oxy-Acetylene Lead-Burning Outfit.

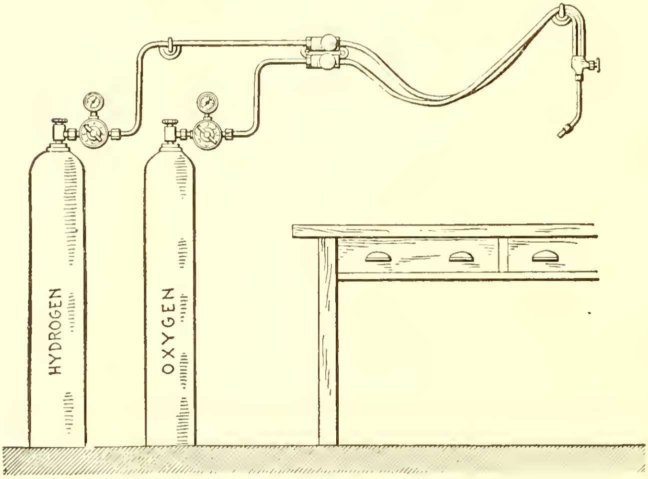


FIG. 88.—Oxy-Hydrogen Lead-Burning Outfit.

and illuminating gas, or others. In order to assist the would-be user, several typical set-ups, taken from the Imperial Handbook, will be shown.

An oxy-acetylene combination is shown in Fig. 87. This shows the bench block *A*, screwed to the wall, which in many cases is the better way. However, it is well to have this block in easy reach of the operator. The oxy-hydrogen set-up is very similar, as shown in Fig. 88.

A hydrogen compressed-air unit is shown in Fig. 89. A constant air-pressure regulator is shown attached to the air line. In Fig. 90 is shown an oxygen-illuminating gas combination. A water seal is used on the gas line as a safeguard and to act as a scrubber to some extent.

A very light outfit, intended for jewelers, dentists, or ex-

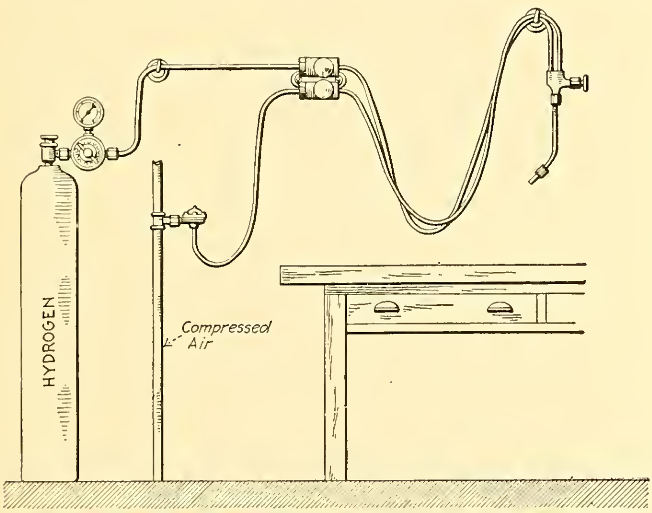


Fig. 89.—Hydrogen and Compressed-Air Outfit.

perimental laboratory work, is shown in Fig. 91. The bench block differs some from the ones just illustrated. The torch itself is almost as light and is about the size of a large fountain pen. With the bench block close to the operator, the torch valve is not needed. This outfit is made by the Davis-Bournonville Co. A very convenient feature is the torch-holding clip, shown at the top of the bench block. This obviates the necessity of laying the torch down at any time, with its attendant danger of fire.

A Gas Flow Indicator.—It is often desirable to measure the flow of gases used in a welding or cutting torch. For this purpose, the Hydrate Engineering Corporation, Buffalo, N. Y., has produced the Hydrex Flow Indicator shown in Fig. 92. In Fig. 93 the principle on which it works is outlined. The gas enters the nipple *a*, as indicated by the arrow. Thence it flows into the chamber *c*, up through the tube *d* and out the nipple *b*. As the gas passes into tube *d* it raises the plunger *e*. The greater the flow of gas the higher will the plunger be lifted. The disk *f* is suspended from plunger *e* and is visible through the gas tube *g*, so that the flow of gas is indicated on a scale calibrated in cubic feet per hour, reduced to normal

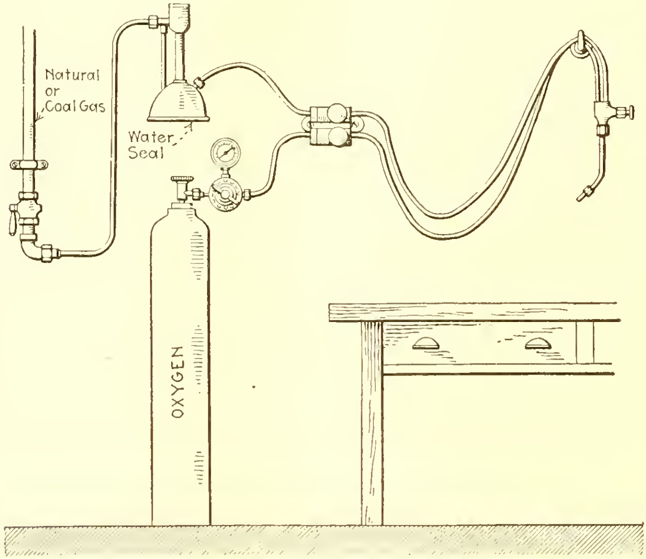


FIG. 90.—Oxygen and Illuminating Gas Outfit.

conditions for a gas flowing at a definite pressure and a definite temperature.

The gas at the time it is measured, may flow at a known pressure and a known temperature, which do not coincide with those for which the calibration is prepared. In such a case the reading has to be converted into the proper volume, by applying those formulas which govern flow of gas through orifices.

These calculations, of course, should not be necessary for a conveniently applicable apparatus. The elimination of computations is accomplished by the use of a chart, which permits the conversion of a reading for any pressure and temperature. This is practical in the laboratory where close observation and intelligent interpretation of the chart may be expected. For the ordinary shop work it is out of place.

To make the instrument a practical and convenient shop and an all-around test apparatus, it was necessary to simplify the determination of the volume passing through the flow in-

Fig. 91.—Manufacturing Jewelers' and Dentists' Welding Outfit.

dicator. A pressure gage makes this possible. This pressure gage indicates factors instead of pressures in pounds per square inch. The reading on the flow indicator scale, multiplied by the factor, is the actual volume of gas, reduced to normal conditions, passing through the flow indicator. Thus, the shop operator is relieved of all complicated mathematical considerations and he may concentrate his energies upon his work.

The influence of the temperature upon the reading is approximately 1 per cent for each 10 deg. F.

The influence of the pressure upon the volume is inverse to that of temperature, increasing temperature *decreases* the density of gas, while increasing pressure will *increase* the density.

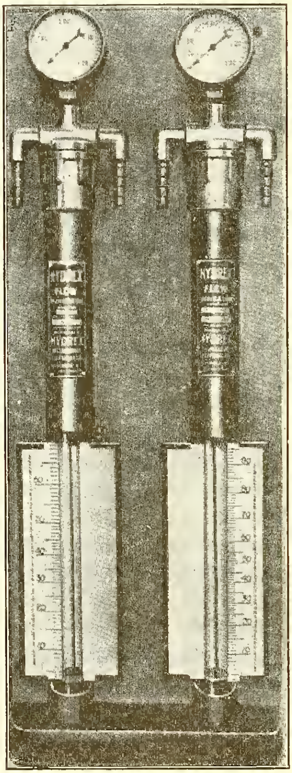


Fig. 92.

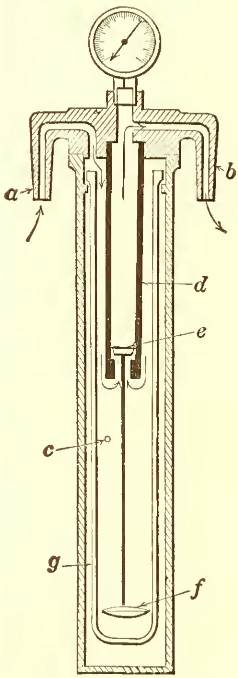


Fig. 93.—Details of Gas Flow Indicators.

On a calibration made for 40 lbs./in.^{2} gage pressure, the increase of one pound in pressure compensates for an approximate increase of 10 deg. in temperature; and if the calibration is for 10 lbs./in.^{2} gage pressure, an increase of $\frac{1}{2}$ lb./in.^{2} pressure will compensate for an increase of approximately 10 deg. F.

CHAPTER IX

LEARNING TO WELD WITH A GAS TORCH

Directions as to how to handle a gas torch and to weld are of no use without actual practice—and lots of it. However, the would-be welder should have certain definite instructions given him before he attempts to do any work. To become a *first-class all-round* welder requires long experience, a mechanical sense, and a liberal application of brains as a flux on every job. Learning to do simple, one-operation welding jobs, however, is comparatively easy if a competent instructor is to be had. If such an instructor is not to be had, the directions given here will serve as a foundation upon which a fair knowledge of the work may be built. It is easier to learn to cut than it is to learn to weld, but as welding is the more important of the two the method will be described first.

It is taken for granted that the welder, following directions already given, is familiar with his apparatus, has the correct size of tip for the metal to be welded, knows how to light his torch and has ample gas for the work. In making a gas-torch weld, it is necessary that fusion penetrate entirely through the metal. In order to aid this the pieces are usually chamfered or beveled with an air hammer, a grinder, or cold chisel. By beveling is meant the grooving or chamfering of the metal at the line of the weld, the depth of this groove or V being equivalent to the thickness of the metal.

Beveling is not required on castings or plates lighter than $^1/_8$ in. in thickness. From $^1/_8$ in. to $^3/_{16}$ in. in thickness a chamfer of 45 deg. on each piece, or a total angle opening of 90 deg., is about right. From $^3/_{16}$ in. up to the maximum thickness weldable by the gas torch, an angle opening of from 60 deg. to 90 deg. is used, the angle being dependent somewhat upon the nature of the material and the location of the weld. On very thick metal a channel with parallel sides, beveled only at the bottom, is frequently used.

Under certain conditions it is advisable, but seldom economical, to use an oxygen cutting torch for beveling. In case this is done, care must be taken that all the oxide produced on the surfaces cut by the torch is removed before welding. The beginner should start by welding strips of rolled iron or steel $\frac{1}{8}$ in. thick and about $1\frac{1}{2} \times 6$ in. These may be welded without the use of a welding rod. The pieces must be properly cleaned and free from scale, grease or dirt. The operator must wear suitable colored goggles, and should grasp the handle of the torch firmly. It is not good practice to hold it in the fingers, because it is impossible to manipulate

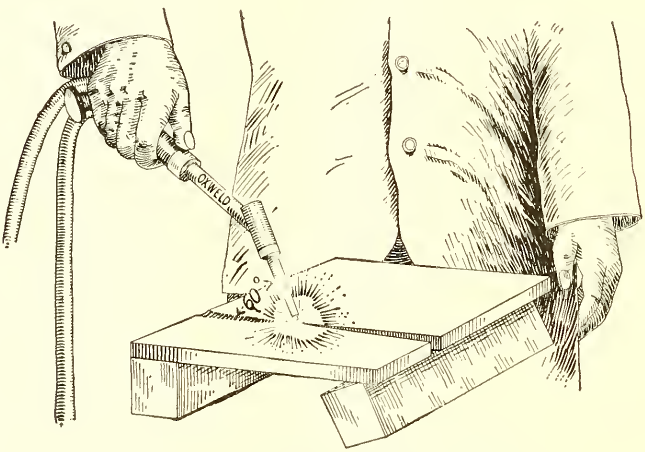


Fig. 94.—The Way to Hold the Torch.

the flame with as great regularity and control, nor will it be possible to do as heavy work without tiring.

Occasionally, the hose is thrown over the man's shoulder. In this case the weight of the torch is suspended and held by the tubing, so that it is only necessary to impart the typical welding motion to the torch, which can usually be done by the fingers. The movement of the welding flame is hindered, however, and this method is therefore not recommended. It should be used only as a relief when the work is of long duration and the operator's wrist and forearm become tired.

The head of the torch should be inclined at an angle of about 60 deg. to the plane of the weld, as in Fig. 94. The inclination of the head should not be too great, because if it is the molten metal will be blown ahead of the welding zone and will adhere to the comparatively cold sides of the weld. On the other hand, the welding head should not be inclined too near the vertical, because in that case the preheating effect of the secondary flame will not be efficiently applied.

There are certain cases, however, where the conductivity of the metal is such that it is not necessary to utilize this preheating. Also certain metals have the property of absorbing the gases of the flame. Consequently, in these cases it is best that the flame impingement be concentrated to as small an area as possible.

Torch Motion.—The motion of the torch should be away

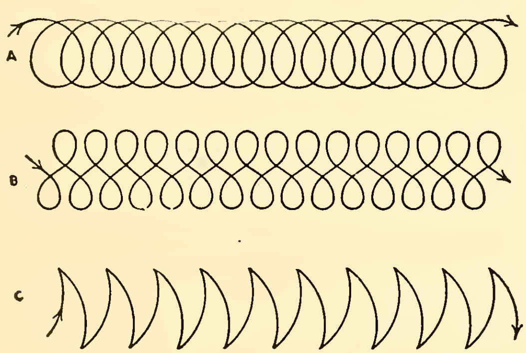


Fig. 95.—Different Flame Movements.

from the welder and not toward him, as closer observation of the work can be obtained and greater facility in making the weld will be experienced.

Where very thin sheet material is being welded and it is not necessary to use a welding rod or wire, a weld may be produced by moving the torch in a straight line. It can readily be seen that this does not apply to welds which have been beveled, and which require the use of filling material, for in this case a swinging motion must be imparted to the torch to take in both edges of the weld and the welding wire at practically the same time.

In comparatively light work a motion is imparted to the torch which will cause the incandescent cone to describe a series of overlapping circles, the overlapping extending in the direction of the welding, as shown at *A*, Fig. 95. In order that the weld be of a good appearance this must be constant and regular in its advance. The width of this motion is dependent upon the size of the material being welded and varies according to the nature of the work. In some cases a movement like a figure 8 is used, as shown at *B*, but this is a rather complicated one for a beginner. In heavier work, if the system described were used, a great deal of the motion would be superfluous. Consequently, either an oscillating movement, or one in which the jet of the torch will describe semi-circular zig-zags, as at *C*, should be used. This confines the welding zone; and while the progress is not so fast, it is more thorough than the other system for this class of work.

To the average beginner the regular control of these motions is difficult, and considerable practice is required to become skilled. It is the regularity of these motions that pro-

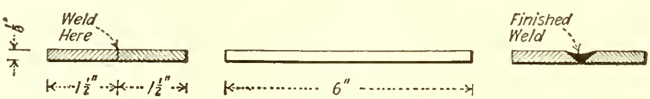


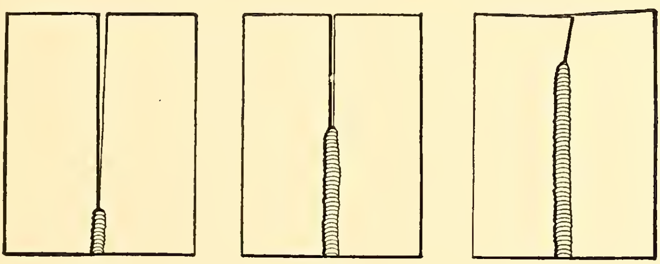
Fig. 96.—Plates and Finished Butt Weld.

duces the characteristic even-rippled surface of good gas-torch welding. The progress of a welder and the quality of his work can be determined to some extent by the skill with which he produces this effect.

On the practice pieces of ⅛-in. thick material, the operator should so manipulate the jet as to take in about ⅛ in. on each side of the joint. The point of the cone of the flame should be held about $^1/_{16}$ in. from the metal, but not actually touching it. On thicker metal the distance of the cone tip will need to be greater, or about ¼ in., depending on the size of the tip used. It is far better to have the torch too far away than too close, as a hole may be blown through the metal. Start to weld at the end of the joint, and as the metal commences to get red give the torch a swinging motion from side to side. Keep this up until the corners of the plates are run together clear through their thickness. Then go on until the entire length is welded. Do not move the torch any faster than necessary to give the metal a chance to run together properly. Be sure that the bottom edges of the plates are melted together before going ahead farther. The plates and the way finished weld looks are shown in Fig. 96.

Care should be taken not to touch the torch tip to the metal, as this will obstruct the flow of gas and may cause it to backfire and burn inside the tip. In such a case, shut off the oxygen at once, then the gas, and cool the tip in cold water. Then relight according to previous instructions.

Do not go back over the weld unless absolutely necessary. Do not run the hot metal on top of the cold metal. Do not leave blowholes, scale nor low spots in your weld. A blowhole is a bubble in the metal. It sometimes occurs alone, and other times there are several of them. It maks the metal look spongy



A B C

FIG. 97.—Plates Welded Without Proper Divergence.

or porous and is caused by not properly running the metal together or by leaving impurities in the weld.

When metal is melted, a coating which flakes off is formed. This coating is called scale and is bluish steel-gray in color.

Low spots are unfilled spaces in the metal caused by moving the torch too fast or unevenly.

The beginner will soon discover that two pieces laid with the edges close together will not weld properly, as they will at first diverge, as shown at *A*, Fig. 97. Then they will gradually draw together as at *B* when the weld is about half done. From this point on the edges will draw in until they overlap about as shown at *C*. There are two methods of overcoming this: The first is to "tack" the two strips at intervals, as shown at *A*, Fig. 98. This method, however, has the disadvantage of causing buckling or warping under certain conditions. This warping may in some cases be eliminated by rolling or hammering after welding. The second, and more satisfactory method, is to diverge the plates, as shown at *B*. The amount of divergence is dependent to some extent upon the thickness and nature of the metal, but it is safe to say that this divergence should not be less than $2\frac{1}{2}$ per cent, nor more than 6 per cent of the length of the weld. Some operators stick to the hard and fast rule of $\frac{1}{4}$ in. per foot, which is a very satisfactory figure in general. However, to obtain the best results it is sometimes best to deviate from this, as practice and experience dictate. In welding a sheet-metal cylinder, it is often necessary to insert a wedge or pin, as shown at *C*,

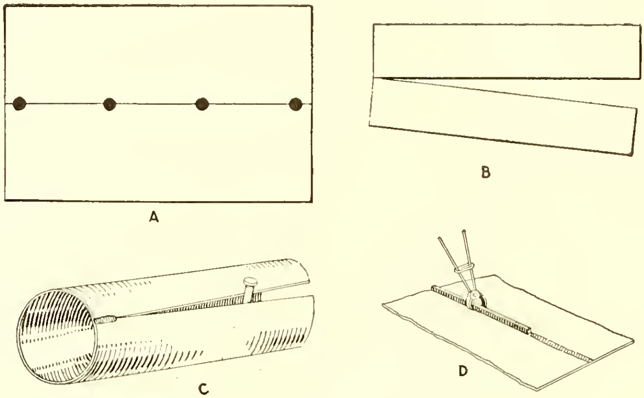


FIG. 98.—Methods of Allowing for Seam Contraction.

in order to obtain the proper separation and prevent overlapping.

On very thin sheets, it is usually advisable to flange the edges, instead of trying to butt weld with or without adding material from a welding rod. The flanges are turned as shown at *D*. The flanges may be tacked as for butt welding, or clamped with tongs, as shown. In regular manufacturing work, where the welding proceeds rapidly, it is common to have a helper move the tongs ahead of the welder. Any warping can, as a rule, be easily ironed out of the thin sheets. In some cases, the edges are lapped and both edges welded, either using a welding rod or not, according to the nature and uses of the parts being welded.

It is very important that the beginner should test his work by bending the metal sharply at the weld and carefully inspecting for defects, which should be overcome on the next piece. The tendency of a beginner is to experiment on all sorts and thicknesses of metal, but he will progress faster if he sticks to one kind and thickness until he masters it. The beginner, as well as the more experienced welder, should occasionally test his flame to be sure he is maintaining the proper neutral flame. This is done by turning off the oxygen until a shadowy point appears on the cone. The oxygen is then turned on again until this shadowy point just disappears into the cone. The reason for this testing of the flame, is that changes in temperature of the torch or variations in pressure may alter the flame without the operator's knowledge, and thus injure the weld by either carbonizing or oxidizing the metal, according to whether there is an excess of acetylene

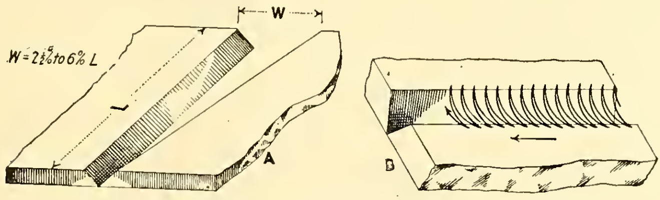


FIG. 99.—Beveled-Edge Plates and Flame Movement.

or of oxygen. If the tip should become clogged from any cause, it should be cleaned out with a soft wire or a piece of wood, taking care not to get the hole in the tip out of round.

Using the Welding Rod.—In starting to use the welding or filling rod, it is just as well to begin to weld pieces similar in size to those used for the first lessons in welding, except that the pieces should be about ¼ in. thick, and beveled on one side of the edges only. The amount of divergence is judged as in the case of the plain butt-welding work, as shown at *A*, Fig. 99. The flame movement is indicated at *B*.

The welding rod should be held and inclined as shown in Fig. 100. In this position sufficient quantity of metal may be added at the right time. With the welding rod held in a vertical position or horizontal, the possibility of the addition of an excess of metal, part of which is not fused, is great. In adding this metal, care must be exercised that the edges of the weld are in the proper state of fusion to receive it. If the metal is not sufficiently hot, the added material will merely stick to the sides and fusion will not exist. It is therefore necessary that, by the motion of the torch, fusion be produced at the edges of the weld equal with that of the welding rod.

The usual faults of the beginner are failure to introduce the welding rod at the proper time into the welding zone, to hold the rod at the wrong angle, or to fuse either too little or too much of the rod. The filling material when melted should never be allowed to fall into the weld in drops or globules. When the proper time arrives to add it, the welding

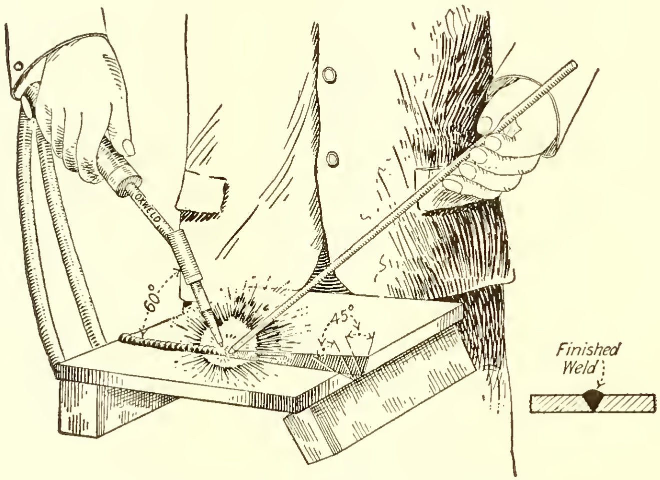


FIG. 100.—Using a Filling Rod in Welding.

rod is lowered into the weld until it is in contact with the molten metal of the edges. When in this position the flame of the torch is directed around it, and thus fusion is produced.

It is customary to add metal in excess of that of the original section, and round it over nicely.

There are several very important reasons for doing this. First, the weld is reinforced and the strength is accordingly increased. Second, in case a finished surface is desired a sufficient stock must remain to allow for finish. Third, small pinholes or blowholes may be found just under the surface of the weld, which do not extend to any depth, and may be removed by filing or machining.

In some cases the plates do not start to draw together until the weld has nearly reached the center. In a case of this kind it is good policy to slow down the welding. After the weld has been completed to the center, the plates will commence to draw together more rapidly, and in case the plates draw

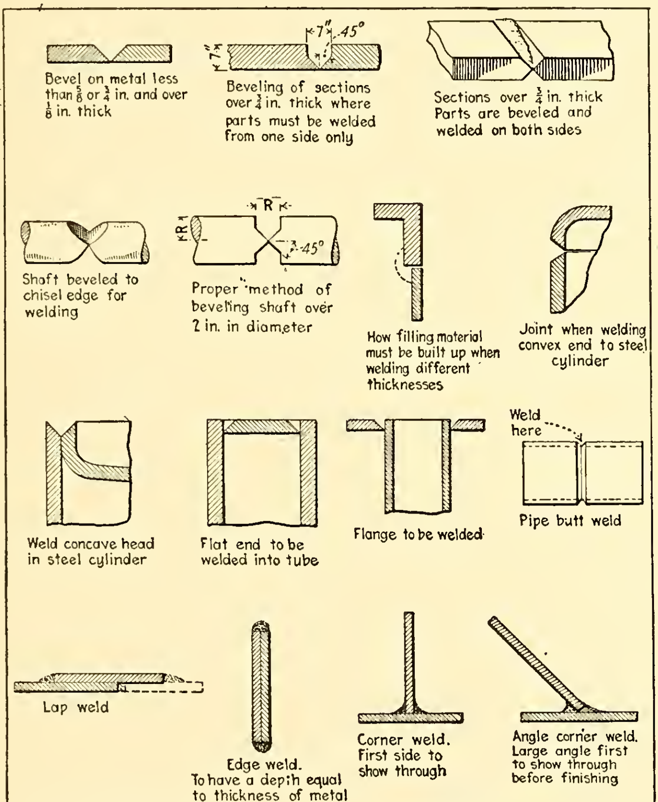


Fig. 101.—Various Examples of Welding Jobs.

too fast, speed up on the welding until the proper distance is secured between the two plates.

After the beginner has practiced until he can make a good weld on the plain and beveled plates, as suggested, he may practice on the forms shown in Fig. 101. These forms represent most of the kinds he will encounter in the regular run of work in a job or general repair shop.

Sources of Trouble.—It will be well to repeat to some extent, the instructions and advice previously given, in order to emphasize the danger points:

The first source of trouble in making a weld is improper adjustment of the welding flame. If the flame is not adjusted properly the resultant weld will be inferior. The commonest fault is the presence of too much oxygen. In this case, unless the welder takes a great deal of care in removing the oxide by mechanical means, it will be incorporated throughout the weld. The presence of oxide prevents the thorough blending of the metal, and therefore decreases its strength.

Failure to penetrate to the bottom of the weld is the cause of a great many defects. This fault is not only that of a beginner, but also that of the more skilled operator. Very often the desire to complete a weld rapidly will cause the operator to hasten over the most important part of his work, which is to secure the absolute fusion of the edges at the bottom of the weld, before filling rod is added. This defect not only reduces the section of the weld, but also produces a line of weakness in case the weld is submitted to bending or transverse strains.

When molten metal is added to metal which is not in fusion, a weld is not secured. The molten metal merely sticks to the cooler metal; this defect is common with careless operators. It may be caused by improperly beveling the pieces to be welded, by the faulty manipulation of the torch or by improper use of the welding rod.

For the beginner it is at first difficult to distinguish the proper temperature at which to add the filling material. Usually he applies the filling rod before the edges of the weld are in fusion. The adhesion in this case occurs at both edges. Occasionally, one edge of the weld is in fusion, but the other is not, in which event the adhesion is restricted to one side.

In some cases the edges of the weld are both at a point of fusion too soon. Under these conditions a film of oxide may exist on each edge. When a filling material is added, adhesion is produced with a film of oxide separating the edges and the added material. Quite often an operator, in applying the welding rod to the weld, will concentrate his flame on the welding rod and the edges of the weld. As he plays the torch around the rod he will inadvertently force some of the molten metal ahead. The metal not being in the proper state of fusion, there will consequently be only a small area of adhesion.

In welding cast iron, copper, and to some extent steel, a very common fault of the beginner is that of forming blow-holes or porous sections in the weld. This can be overcome by close observation of the work while welding and by certain corrective means, the principal one of which is the use of proper fluxes and proper manipulation of the welding rod.

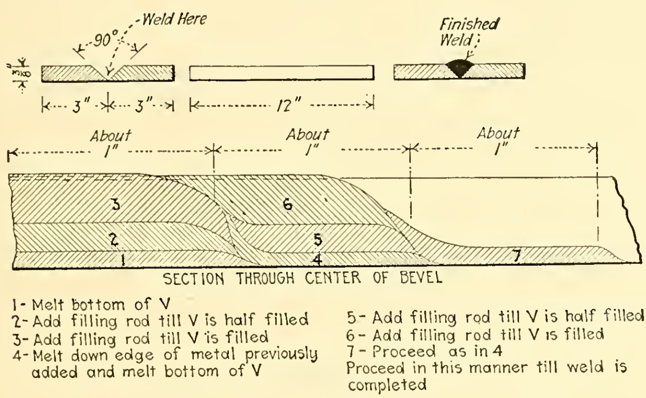


FIG. 102.—Method of "Building Up" a Weld.

It is needless to say that the existence of such defects in a weld seriously affect its ultimate strength.

Occasionally, welds are encountered in which dirt or some foreign material is incorporated. This will cause porosity and an inferior weld, which could readily have been avoided by removing the material either before or during the execution of the weld.

Built-Up Welds.—Where steel of considerable thickness is to be welded, the Oxweld company recommends the method illustrated in Fig. 102. In the example selected the steel plates are $\frac{3}{8}$ in. thick, beveled 45 deg. on each edge, making an included angle of 90 deg. In doing the work in this way, first melt the edges of the bottom of the V together for a length of 1 in. Add the welding rod to this length until the V is about half filled. Be sure that the sides of the V are melted when the rod is added. Then go back over this and fill up the V $^3/_{32}$ in. thicker than the original plate. When this length of weld is done, melt the edges of the plates ahead down into the bottom of the V, and at the same time being sure that the end of the weld already finished is melted and flows into the botton of the V. Then add to this next section metal until a reënforcement of $^3/_{32}$ in. greater than the thickness of the plate is formed. Keep on in this way until the plates are welded. Near the finish of the weld it is necessary that the rod be given a slight swinging motion, similar to the torch. This is in order that the top of the V be entirely covered.

Vertical Welds.—Where plates are to be welded with the seam in a vertical position, the same rule for the amount of divergence is used as for those in any other position. The weld should be started at the bottom and carried upward without stopping until the weld is completed. Practice on work of this kind will give the welder experience in the control of the molten metal as no other kind of weld will, and he should put in considerable time on this work.

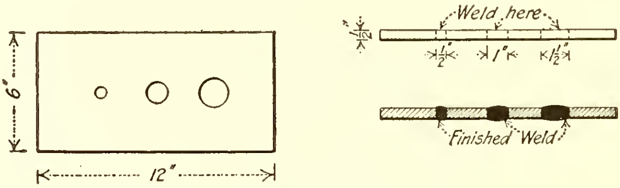


FIG. 103.—The Way to Fill Up Holes.

Filling Up a Hole.—A thing that every welder should learn as soon as he has mastered the simpler welds, is to fill up holes properly. A good way to learn is to take a piece of $\frac{1}{2}$-in. plate and drill three holes in it, $\frac{1}{2}$, $\frac{3}{4}$ and $1\frac{1}{2}$ in. in diameter, as shown in Fig. 103. The beginner should commence with the smaller hole first. The weld should be started by melting down the top edge of the hole in one place. This will give a slight angle to one side. On the face of this angle metal is added. The hole is built up by adding metal continuously from the bottom to the top until it gradually closes up. The welding should be carried on around the hole, however, and should not be built up from one side only. When the hole is properly filled in, the metal should meet at the center. Proceed with the $\frac{3}{4}$-in. hole and the $1\frac{1}{2}$-in. hole exactly in the same manner. Turn the plate over and clean up the bottom side by melting the excess metal with the torch.

Forming Bosses or "Putting On" Metal.—The forming of bosses, building up missing parts, or putting on metal where needed, forms a very important part of a welder's work. Consequently, the beginner should practice work of this kind as soon as he has mastered the ordinary run of welds outlined. He can begin by building up bosses an inch or so in diameter and 1 in. high on a steel plate, keeping at the work until he can produce a boss of fairly regular outline. He can then practice on square or rectangular bosses. Built-up bosses of this kind are shown in Fig. 104. Since the welder has already practiced vertical welds he should have little trouble in placing

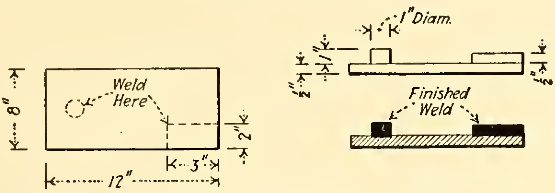


FIG. 104.—Building Up Bosses.

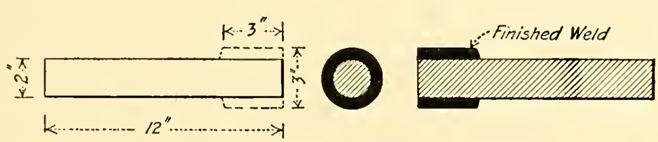


FIG. 105.—Putting a Collar on a Shaft.

his metal where it is wanted. Care, however, should always be taken to make sure that there is perfect fusion of the added metal and the plate before building up the boss. If a good weld to the surface of the plate is not made, the rest of the work is worthless. Be sure that all scale and dirt are worked out of the metal.

Another type of built-up weld is shown in Fig. 105. In making a weld of this kind for the first time, take a piece of 2-in. shaft, 12 in. long and clean off the surface for about 3 in. at one end. Use a $^3/_{16}$-in. welding rod, and a No. 10

Oxweld tip, or its equivalent, and 21-lb. oxygen pressure. Place the flame of the torch on one spot of the surface until it is melted. Then add the welding rod. Add a layer of 1 in. wide and 3 in. long along the shaft. Make this layer $\frac{1}{4}$ in. thick. When this strip is finished, weld another strip on top of it, starting at the end just finished. This gives a strip of added metal 1 in. wide, 3 in. long and $\frac{1}{2}$ in. thick. When this is done, start another strip at the side of this, being careful that the metal of the shaft is melting before the welding rod is added and also that the edges of the first two layers are at the same time melted down to the shaft. Proceed with the welding exactly the same as just described, adding strip

Fig. 106.—Building Up Gear Teeth.

after strip, side by side, until the end of the shaft is covered all around. Remember that the shaft must be melted before any metal can be added, that each layer must be melting before another layer can be added to it, and that each strip must be welded both to the shaft and the strip next to it. When the shaft is completely covered, the end of the weld should be gone over with the welding flame, in order to clean it up and to be sure that a weld is produced at this point.

Following the building-up work just outlined, it is a good thing to practice building up worn- or broken-out teeth in old or scrap steel gears, as shown in Fig. 106. Before a welder attempts to do any actual repair work on gears, however, he should first learn more about expansion and contraction, and the methods of overcoming their effects.

WELDING BACKWARD

In an article published in the "Acetylene and Welding Journal," London, England, Capt. D. Richardson describes a method of welding which differs considerably from the generally accepted American practice.

In 1916, M. Roulleau, a French acetylene engineer, was sent by his firm to Italy in connection with the manufacture of large welded projectiles. The welds were being made by welders with little knowledge of the process and examination showed that from the number of defective welds obtained it would be difficult to get worse results. The welds were porous, adhesion was common, and the solidity of the joints was extremely bad. The supervision of the 1000 to 1200 welders distributed through seven or eight different works was a serious problem. The daily consumption of oxygen and carbide, at a cost of thousands of francs, in producing work of the type described made it an urgent economic problem to bring about improvement. Faced with these various problems, M. Roulleau, after experiment, introduced the method of welding backward into the various Italian workshops which came under his technical supervision. This change in method produced excellent results and on returning to France after a mission of three years in Italy, M. Roulleau collaborated with the Union de la Soudure Autogène with a view to a wider application of his method.

Welding backward may be defined as the method of executing a weld in which the welding rod follows the torch as opposed to preceding it. Or again, it may be defined as a method in which the flame is inclined towards the welded portion. A fuller and perhaps better definition would be: The flame is inclined backwards and only undergoes a slight transversal motion in addition to its regular advancement, the welding rod follows the flame and is given a movement, the end of the rod always being molten.

It is claimed that, having acquired the method of welding backward, the welder will find it easier to execute welds and that the penetration is always satisfactory; adhesion is almost impossible; the metal is sound; there is a diminution in the amount of oxide, and the metal is more ductile. Finally, that the speed of welding is greater than with the old method from which it will be gathered that there is economy in labor and gases. The economy in the consumption of filling material is of the same order as it is possible to reduce the beveling angle.

APPLICATIONS OF METHOD

This method of welding is applied mainly to steel plate above $^1/_{16}$ in. in thickness. It should be used on all plates falling in the range of $\frac{1}{8}$ to $\frac{1}{2}$ in. in thickness.

The process is particularly valuable for certain industries such as the manufacture of boilers, etc.

Its application to mild steel has been specially studied. A number of experiments have shown that welding backward gives better results than the usual method when welding steels with a higher carbon content—medium and hard. It is not satisfactory for aluminum welding and gives indifferent results when welding cast iron. On the other hand, the first series of tests in using the method when welding copper and brass have proved satisfactory.

When comparing this method of executing welds with other methods, one might say that welding backward is a "more mechanical" method. From this it follows that more definite rules have to be observed in executing welds and it is advisable, especially for beginners, to strictly observe the rules laid down. These instructions, which are the result of investigation, may subsequently be modified and added to, but in the meantime they give good results and should be followed.

For example, it will be noticed that for this method of welding, the edges of the two pieces of metal to be welded should be chamfered or beveled, so that when they are placed together, the two beveled edges form a V. Although the angles of the bevel can be reduced, beveling is still indispensable, even on thin material.

PREPARATION OF MATERIAL

The parts to be welded are prepared in the ordinary way, tacks, or short welds, at intervals of from 2 to 6 in., according to the thickness of material may be used. In the absence of jigs, the parts are supported so that the lower edges are in the same horizontal plane. The angle of the V formed by the two beveled plates should never exceed 90 deg., and, as already mentioned, for this method can be distinctly less. Beginners can gradually reduce the angle of the V from the previous standard of 90 deg. until they arrive at 60 deg. for material $\frac{1}{4}$ in. in thickness or above, and for material between $\frac{1}{8}$ in. and $\frac{1}{4}$ in. an angle of between 45 and 50 deg. can be used.

The beveling should be carefully done and extend the full depth of the plates as partial beveling will produce defective welds.

The power of a torch. in other words, the quantity of heat which it is capable of giving out in a given time, is generally measured by the number of cubic feet of acetylene burnt in an hour with the flame perfectly regulated. The rule which has been adopted for welding steel by the usual method of executing welds can be followed, namely, that the consumption should be about 5 cu.ft. of acetylene per hour for every $^1/_{16}$ in. in thickness. So that for material $^3/_{16}$ in. thick, a torch consuming about 15 cu.ft. per hour would be required, for $\frac{3}{8}$ in. one consuming 30 cu.ft., and so on. However, it will be found that beginners obtain the best results by using a less powerful torch than indicated, whilst the more expert welder rapidly reaches the stage where he can advantageously use a more powerful one, as for example, for $^1/_8$-in. material a torch consuming 5.3 cu.ft.; for $^3/_{16}$-in. material one consuming 20 cu.ft.; and for $\frac{3}{8}$-in. 40 cu.ft.

SIZE OF ROD

The choice of the right size of welding rod is of great importance. A rod that is too small melts too freely, has a tendency to burn, and is distributed badly. The defects of adhesion and oxide inclusions are common. If the wire is too large, the rate of welding is retarded, the molten bath is cooled, and it is difficult to add the metal uniformly. In both cases burning and overheating of the welding rod and material are likely to take place.

The following table gives the sizes of rod for welding various thicknesses:

Thickness to be Welded In Inches	Diameter of Wire S. W. G.	Decimal Equivalent	Nearest 1/64
1/8	14	0.081	5
5/32 to 3/16	11	0.116	8
1/4 to 9/32	8	0.160	10
11/32 to 13/32	6	0.192	12
above	4	0.232	15

POSITION OF TORCH

The flame of the torch should be given a definite inclination. In certain cases and especially with expert welders, familiar with the

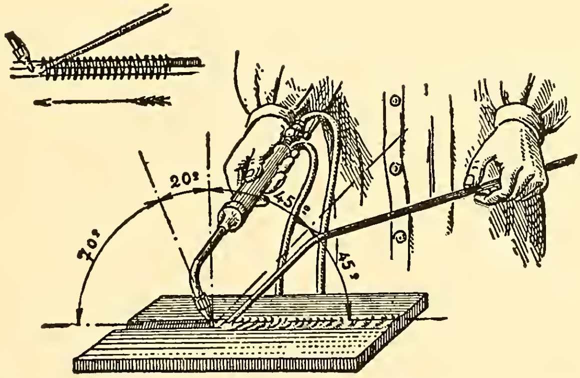


FIG. 107.—Position of Torch and Rod for Backward Welding.

backward method of executing welds, this inclination of the flame to the plane of the weld is very small, in other words, the flame is almost perpendicular to the weld. However, it has been found that an angle of 20 deg. gives the best results, that is to say, the angle between the nozzle of the torch and the perpendicular should be 20 degrees, the flame being turned backwards as shown in Fig. 107. Beginners should pay particular attention to obtaining and practically working at this angle of inclination.

In welding backward it is the welding rod that is given a movement and not the torch. The torch is therefore held in such a manner that the flame advances along the bevelled faces with as great a regularity as possible, the rate of movement being in proportion to the speed of welding. A very slight transversal movement may be given to the torch to produce more rapid fusion of the two bevelled faces.

The white cone of the flame should penetrate very deeply into the angle of the V as shown in Fig. 108. If held too high as shown in Fig. 109 the melting at the bottom of the V is not sufficient, the size

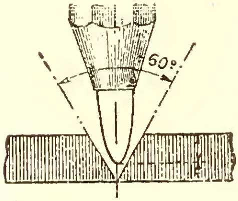


Fig. 108.—Position of Flame.

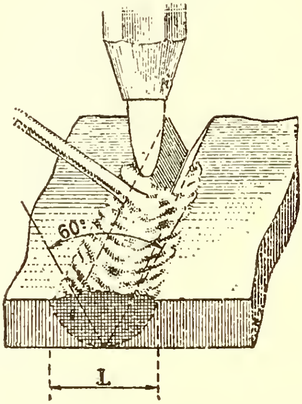


Fig. 109.—Wrong Position.

of the weld is unnecessarily increased, the metal near the surface is overheated and the speed of welding is diminished.

The penetration of the white cone should be carefully observed if the advantages, economy and quality of welds, which can be obtained by welding backward are required.

HOW TO HOLD THE ROD

The melting of the metal is produced, as previously explained, behind the torch and not in front as is the common practice.

This melting is not obtained by the welding cone of the flame, but by the additional heat contributed by the envelope of the flame, the torch being inclined towards the rear, in other words, towards the welding wire.

The position of the welding rod and its movement should be closely followed. The rod is inclined to the line of welding, in the advancing direction, that is to say, in the opposite direction to the inclination of the flame. The best angle of inclination, between the weld and the rod, has been found to be 45 deg. for material about ¼-in. thick, and for thinner material, say ⅛-in., an angle of about 30 degrees. This inclination is maintained whilst the welding rod is given its proper movement in the line of welding. This movement for the thicker material, say, about ¼-in., consists in alternately moving the molten extremity of the wire from one side to the other of the line of welding, as shown in the small illustration in Fig.107. The movement for material less than this thickness becomes first of all ellipsoidal or gyratory, and then for material about ⅛-in., and especially when the material is about $^1/_{16}$ in., the movement is translated into a reciprocating one without any transversal movements, as shown in Fig. 110. In both of these cases the extremity of the wire remains continually in the molten bath.

In order that the line of welding should present an homogeneous appearance, it is advisable to operate in the manner already laid down and with the same speed at the commencement and completion of the work. If, say, one of the extremities of the weld is attacked too soon with the torch, free fusion and regular advancement are not obtained until after a certain time, with the result that irregularities are noticeable at the beginning of the weld. To avoid this the plates should be preheated for a length of a few inches with the torch, so as to obtain, at the beginning, regularity, and a normal rate of welding.

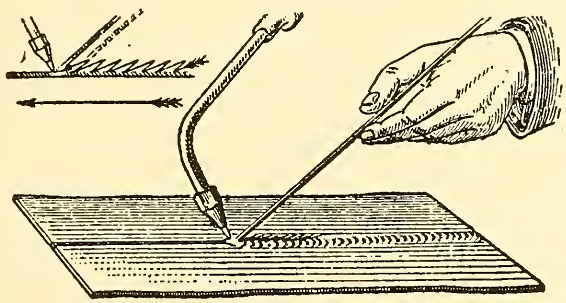


Fig. 110.—Rod Movement When Welding Thin Metal.

The torch and the welding rod being held in the manner indicated, the cone of the flame is directed so as to well penetrate into the angle of the bevel, and the first molten bath is obtained by giving the torch a slight gyratory movement, immediately after which the extremity of the welding rod is introduced into the molten bath and the torch is then given its regular advancing movement.

The welding rod, on the other hand, follows immediately after the flame, and describes a reciprocating or a more or less elliptical and longitudinal motion, according to the thickness of the metal, as indicated and shown in Figs. 107 and 110, taking care to always maintain the given angle of inclination. The weld is thus obtained in a normal and very continuous manner. Care must be taken to use a welding rod which satisfactorily fills the lines of welding, without excess or insufficient addition of material. If necessary, the position of the torch is changed when the extremity of the weld is reached in order to obtain a clean finish as is usual with the ordinary method of welding.

The melted metal being attacked in the rear, as a result of the inclination of the flame, the bevelled faces are always well melted;

the weld is what is commonly said to be well penetrated and the defect of adhesion is almost impossible. However, it is advisable not to travel too fast so as to give the bevelled surface sufficient time to melt freely, otherwise candles of molten metal will appear on the underside of the weld as a result of the addition of too much heat at the bottom of the V.

From the point of view of good penetration of the metal and the absence of the defect of adhesion, welding backward offers considerable advantage over other methods of executing welds and is capable of entirely eliminating these defects.

Etching tests on welds obtained by this method show perfect joining between the metal of the plate and the added metal. The welds show distinctly less oxide inclusions than those obtained by the ordinary methods, and are free from blowholes. In addition they possess ordinary hardness and the remaining mechanical properties are more regular.

Bending tests have given good results. It is possible to fold the weld without starting a crack, which is a very good indication of excellent elongation properties and good penetration of the weld. The tensile strength of the weld is also greater than that of ordinary welds and improvement in the other mechanical properties is obtained.

INSTRUCTIONS FOR LEAD BURNING

The "Eveready" instruction book, issued by the Oxweld Acetylene Co., gives the following hints on lead burning:

The size of the flame used in lead burning depends almost entirely upon the class of work. The 0-H3 and 1-H3 tips are used on very light sheet lead and similar work, the 2-H3 tip on heavy sheet and light storage battery work, and the 3-H3 and 4-H3 tips on general storage battery work.

In all cases where lead burning is to be done, it is essential that the edges of the parts to be burned are first cleaned. Otherwise a film of oxide will form on the molten surfaces of the metal, which will tend to keep the metal from flowing together, slow down the work and quite possibly result in a poor joint. Clean the edges to be joined and also clean the surface a short distance back from the edges, either with a lead scraper or a wire brush.

It is extremely difficult to burn lead which has been subjected to the action of a strong acid, such as the sulphuric acid used in storage batteries. Where it is possible to neutralize the acid by a solution of ammonia or sodium bicarbonate without getting any into the battery and injuring it, that method is allowable. It is decidedly better in all cases, however, to wipe dry the parts to be burned and then scrape them bright. The scraping will remove the layer of lead which has been affected by the acid and will insure a good joint.

LEAD BURNING-STICKS OR WELDING RODS

In some cases additional metal is fused in to completely fill the parts being burned or for reinforcing the joint. Where extra metal is added, the "burning sticks" or rods employed for this purpose are either pure lead or lead containing a percentage of antimony. Pure lead rods are preferable for working on sheet lead or for any part which may be subject to bending strains. Rods containing antimony are preferable where the work is to be threaded or where it must be rigid enough to withstand twisting strains, as for instance storage battery terminal posts.

Hold the torch so that the flame is almost perpendicular to the surface of the work and the white cone almost touches the metal. Be careful, however, *not to jab the tip of the torch in the molten lead*, and under no circumstances hold the torch tip any closer to the work than may be necessary to play the tip of the inner cone of the flame upon it. In all lead burning it must be remembered that the melting point of lead is low and that as soon as it reaches the melting point it will flow rapidly and unless care is exercised it may get beyond the control of the operator. The chief thing to learn is to know when the lead is flowing properly and to lift the flame immediately from that part of the work so that no excess melting will be done. Should the metal start to run away, lift the torch and allow the work to cool before attempting to proceed.

When adding metal the torch flame should be played simultaneously on the rod and along the edges of the work to be joined so that they will reach the fusion point at the same time. It does no good to deposit molten lead upon cold lead. All the lead must be melting, otherwise it will not fuse together.

Do not allow the rod to touch the metal being worked upon, as it will probably stick and become firmly attached.

LAP JOINTS

In burning sheet lead it is always better, wherever possible, to lap the joints, that is, lay the edge of one sheet of lead $\frac{1}{4}$ to $\frac{1}{2}$ in. over the edge of the other. The overlap of both sheets must be thoroughly cleaned, not merely the edges of the sheets. After placing the sheets in position tap lightly with a wooden mallet along the line of lap to bring the two sheets together. Though lapped joints are sometimes burned without the use of burning sticks, they are not so strong as when a filler is used. In the former method the torch flame is merely played along the edge of the overlapping sheet. With a little practice, this class of joint can be made at high speed.

BUTT JOINTS

When the edges of the work are butted together (not lapped), it is possible to burn them together without the addition of metal. Although this makes a very neat appearing joint the use of the rod will insure a stronger joint with less chance of leaving unburned spots in the seam. For a butt joint, the sheets must be cut true and must lie true while being burned. Tapping along the line of burning with a wooden mallet about 6 in. ahead of the burn is desirable.

In tacking, burn a small spot at each end of the seam and if it is a long one, burn small spots at about 6-in. intervals to keep the edges from pulling apart. This is especially important on vertical seams, but it is also desirable on horizontal seams to prevent trouble that may be caused by the edges spreading.

The movement or play of the torch flame is largely a matter of choice on the part of the operator. Some operators prefer a slight circular movement, progressing along the line to be burned, while others prefer to play the flame alternately from each side of the line of burning. For the beginner, the circular movement is probably the better.

In burning horizontal seams lapped or butted joints may be used, and it is desirable to tack before burning. If extreme strength is desired, use the lap joint. In vertical seams lapped joints should be used, and should be tacked before burning. Start from the bottom and work upward. For overhead seams lapped joints should be used and should be tacked before burning. These seams require skill on the part of the operator, and considerable practice will be found necessary before good burning and neat results are obtained.

STORAGE BATTERY BURNING

In battery repair work there are several operations that call for lead burning. It should be noted that great care must be used to see that the work is thoroughly scraped bright before burning and that all oxide and traces of acid are removed. For rods, use antimonial lead if certain that the plate connectors are made of antimonial lead; if uncertain, use pure lead.

Note: Antimonial lead after scraping has a silvery appearance as compared with the blue tinged color of pure lead. Antimonial lead is also much tougher and harder to scrape or pare with a lead scraper or knife.

In burning plates to plate connectors, set up the plates in a burning rack or comb, which will provide for proper spacing and true alignment. The lugs of the plates must extend above the top of the comb. Place the post in position before attempting to burn the lugs together on a lead strap. To burn, play the flame along the ends of the lugs and when they are molten add metal from the rod and form a strap connecting them all and the post. A comparatively large flame should be used to insure perfect joints because the plates must be fused perfectly to the strap and post.

If a slotted plate strap or connector is used, set up the plates as described above with the lugs extending up into the slots. To burn, play the flame along the sides of the slots to bring them and the lugs to a melting point at the same time, then add metal from the rod to fill up the slots and flush the strap off smooth.

BURNING CELL CONNECTORS OR TERMINALS TO TERMINAL POSTS

The connectors should be tapped lightly with a small wooden mallet until they fit snugly around the terminal posts. To secure a good burn, it is necessary that the surface of the top of the terminal post be about $\frac{1}{4}$ in. below the top surface of the cell connector or battery terminal. If necessary, the post should be cut off to insure this feature. To burn, play the flame on the top of the post and bring it and the inner wall of the connector to a molten state, forming a molten pool. To this add metal from the lead rod. As the pool fills up, be sure to watch that the metal on the inside wall of the connector flows into and with the added metal. Continue until the added metal is flush with the top surface of the connector. Then allow the connector or terminal to cool sufficiently so that the lead will not crumple when brushed, clean the top with a wire brush, and again apply the flame and add enough lead to smooth off and finish the job.

It is sometimes impossible to burn on a connector or terminal in one complete operation, because the metal surrounding the cavity becomes overheated. In such cases, stop work as often as the lead seems to be running too rapidly, and allow it to cool before proceeding.

In burning on a terminal in which the end of a cable is imbedded, protect the rubber insulation on the cable with a strip of wet cloth, to avoid burning it.

In battery repair shops it is often necessary to build up a terminal post which was drilled out when the battery was torn down. When building up a post, a mould should be used to hold the metal in place. This mould can be made of sheet metal and should be tapered so as to be easily withdrawn from the finished work. Be sure that the top of the post is in a molten state before adding lead, so that the post and the metal added will be solidly fused. Unless this is done, the joint will be weak.

LEAD BURNING DATA

Approximate results obtained with Eveready Lead Burning Torch:

	Pressure		Gas Consumption	
Size of Tip	Oxygen lb. per sq.in.	Acetylene lb. per sq.in.	Oxygen cu.ft. per hour	Acetylene cu.ft. per hour
0-H3	2 to 3	2 to 3	1	1
1-H3	2 to 3	2 to 3	2	2
2-H3	2 to 3	2 to 3	3 to 5½	3 to 5
3-H3	3 to 4	3 to 4	6 to 10	6 to 9
4-H3	3 to 5	3 to 4	9 to 12	8 to 11

CHAPTER X

MAKING ALLOWANCE FOR EXPANSION AND CONTRACTION

Through his practice work, as already outlined, the beginner in welding has learned a little about the trouble that expansion and contraction may cause when proper allowance is not made. This was shown to some extent when he attempted to butt-weld two plates set close together. The remedy in that case was to allow for the contraction of the cooling metal and weld, by diverging the edges of the plates. From this example alone he can get a slight idea of the tremendous stresses often set up when, for instance, a broken spoke in a flywheel is welded without proper allowance being made for the amount of expansion in heating and contraction in cooling. These stresses *may* be so great as to quickly cause other fractures, or be of such a nature as to cause the subsequent destruction of the wheel. Different metals conduct heat with varying degrees of speed, that of copper being much more rapid than that of steel. On this account the welder must know something of the characteristics of the metal he is working on in order to obtain good results. However, except for the *amount* of expansion and contraction, the same *general* rules apply to all cases. It should be kept in mind at all times, that nothing can prevent this expansion or contraction of metals when heated or cooled, and that allowance in one way or another must always be made.

Where the ends of a broken bar are butt-welded together the parts are free to expand as they are heated, unless rigidly held. Suppose, however, that they are free to move, then when heated the broken ends will move toward each other, pushing the two parts of the bar in opposite directions when the heated ends touch. After the weld is complete, the cooling will cause the metal to contract, drawing the two parts of the bar closer together. In some cases the bar may be shorter than before, depending on the care and skill with which the weld was made. Owing to the fact that the parts of the bar are free to move no bad stresses are set up. Again suppose the bar happened to be part of a frame, as shown in Fig. 111. Then when heated at the break *A*, the ends could only move toward each other, in certain cases causing these ends to upset, or become thicker. After the weld was completed, the metal would start to contract, the tendency being to pull the cross ends in as shown at *B* and *C*. If the metal was ductile —that is, would stretch—it would probably actually bend in as suggested. Wrought iron or steel, for example, would

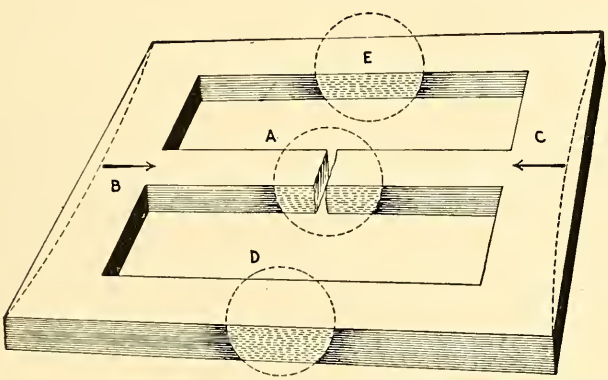


FIG. 111.—Broken Frame with Preheating Zones Indicated.

probably do this. Cast iron would probably break. Aluminum would break or bend, according to the alloy used. In any case it would be a poor job, no matter how well the welding work itself was performed. The way to obtain a good job is to heat the frame at *D* and *E*, so that these side bars will expand as much as the middle one will while being welded. The contraction on cooling will then be the same on all three. Local heating like this is not always sufficient, and it is often necessary to heat the whole piece.

Sometimes conditions are such that neither a part, nor the whole of a piece may be heated properly.

We may then use a jack to open the break in the middle bar a short distance, make the weld, and then slowly loosen the tension on the jack as the metal contracts. Or we may wrap wet cloths or wet asbestos or clay around the middle bar, close to the weld and keep cold water running on it while

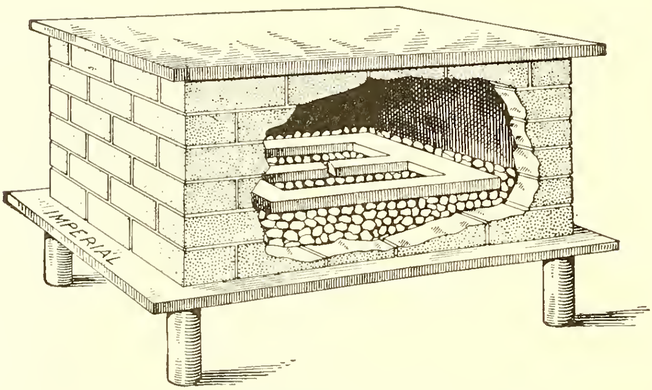


FIG. 112.—Preheating Furnace, Using Charcoal.

welding. This simply holds the expansion to a limited area and should be employed only when no other method is possible. Undoubtedly the better method in nearly all cases is the pre-

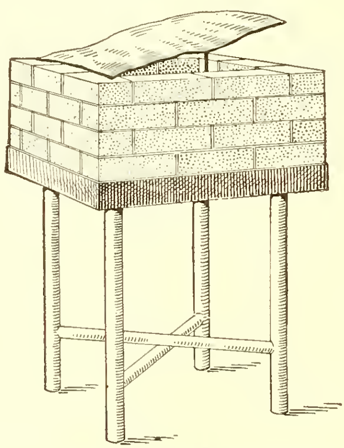


FIG. 113.—Preheating Furnace on an Iron Table.

heating of the article or a portion of it, though in each case proper judgment must be exercised.

The simplest way to preheat work is, as a rule, to build a temporary firebrick charcoal furnace, the form depending on the shape of the work. Where a piece like the frame just mentioned is to be heated all over, a furnace something like the one shown in Fig. 112 is very handy. Often an iron table and furnace like the one shown in Fig. 113 will serve for numerous repair jobs.

USING HEATING TORCHES

Where the nature of the work makes the use of charcoal unsuitable or impossible, a coal gas torch, kerosene torch, or

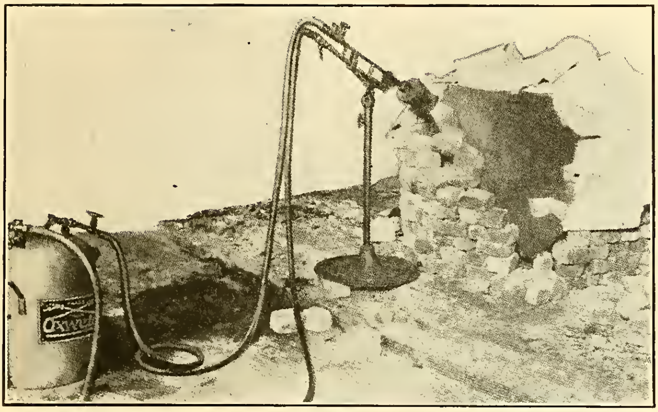


FIG. 114.—Crude Oil or Kerosene Preheater in Action.

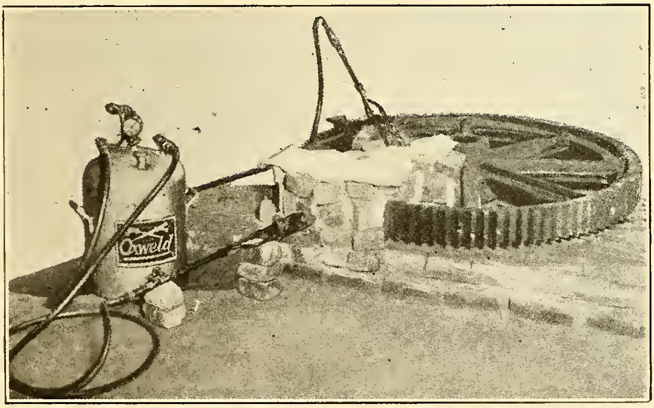


FIG. 115.—Using Two Burners to Preheat a Large Gear.

even the welding flame itself, may be used. The last, however, is too expensive to use except where absolutely necessary. As a rule, a coal gas torch makes a very satisfactory means of preheating if it can be used. In using any preheating flame it is best to build up with firebrick or asbestos in such a way as to confine the heat where wanted. This also saves fuel. An Ox-

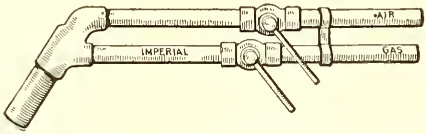


FIG. 116.—A Gas and Preheating Torch.

weld preheater using any grade of fuel, crude or kerosene oil, is shown in action in Figs. 114 and 115. This has two burners, and has to be pumped so as to have about 25 to 50 lb. pressure to get good results. The large size weighs 110 lb. One big advantage of a burner of this type is, that it may be carried any-

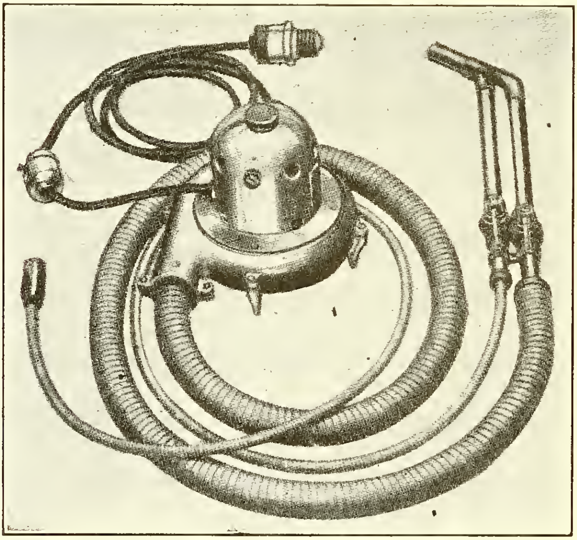


FIG. 117.—Portable Electric Blower-Type Gas-Burning Preheater.

where and used. Where a shop has a compressed-air system and illuminating gas, the type of torch in Fig. 116 will prove exceedingly satisfactory. In case a shop does not have a compressed-air system, but has gas and electricity, the apparatus shown in Fig. 117 may prove useful. This is made by the

Tyler Manufacturing Co., Boston. The motor driving the fan is of the universal type, operating on either alternating or direct

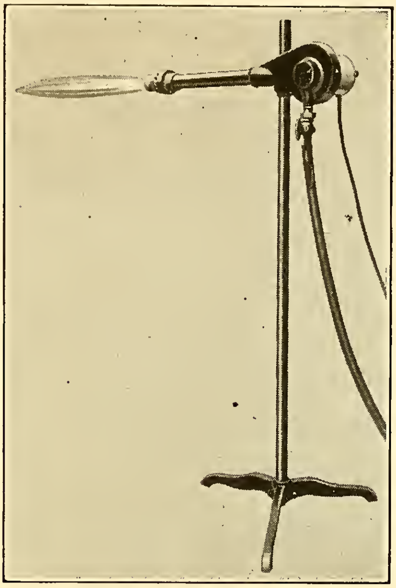


FIG. 118.—Portable Preheater Mounted on a Stand.

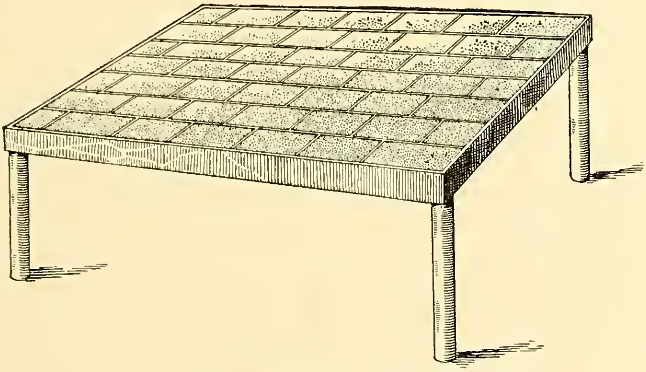


FIG. 119.—Iron Table With Firebrick Top.

current. One motor will supply air enough for four regular size burners.

Another torch is shown in Fig. 118. This also uses illuminating gas, the air being supplied by means of an electric driven fan. This device is made by the North American Manufacturing Co., Cleveland, Ohio. It is claimed that from 500 to 2500 deg. F. may be obtained with this torch.

For welding work of all kinds where proper alignment must be maintained, a table with a heavy cast-iron top is almost indispensable. Tables of this kind may be obtained from almost any of the supply firms. The Imperial Brass Manufacturing Co., Chicago, supplies a table with a firebrick top, as shown in Fig. 119. This kind of a table is very handy, as it enables the welder to construct firebrick furnaces of all kinds, and to so box in his work as to conserve all the heat possible. It also brings the work up to where he can work on it to the best advantage.

COOLING WORK

The cooling of steel or iron work after welding is often as important as the preheating. Some work must be annealed after it has cooled, by heating to a red heat and then slowly cooling again. Small parts may be buried in slacked lime, ashes or the like. Flat work may be laid in a sheet-iron box partly filled with lime and covered with sheet asbestos or more lime. In any case, the weld should be protected as much as possible from drafts. Where a firebrick furnace has been built up around some part, it may be closed in and the work allowed to cool as slowly as possible. The welder must use good judgment in all cases. It must not be thought that preheating is only necessary to take care of expansion and contraction, for while in small work this is often the only consideration, on large work it saves expense. By this it is meant that the use of charcoal, gas or other heating mediums is much cheaper than to try to bring the parts to be joined up to a welding heat with the welding flame alone.

The way in which expansion and contraction will take effect often requires considerable study. If the work can be heated all over, this is often the best way. As already mentioned, this is often not possible, so in order to assist the beginner, a number of examples will be given showing just where certain jobs should be preheated to get good results. A good thing to keep in mind as to where to preheat, is to imagine a wedge driven in at the break and note what places this action would put under strain.

THE WIEDERWAX PREHEATER

A preheating furnace suitable for both preheating and slow cooling is shown in Figs. 120 and 121. This heater is made

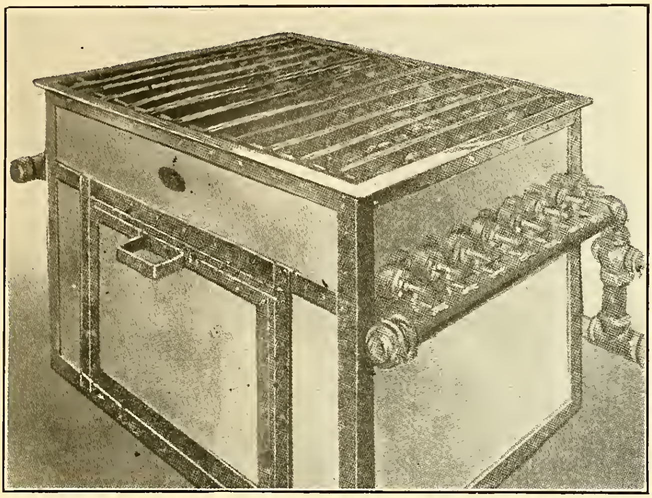


FIG. 120.—The Wiederwax Preheater.

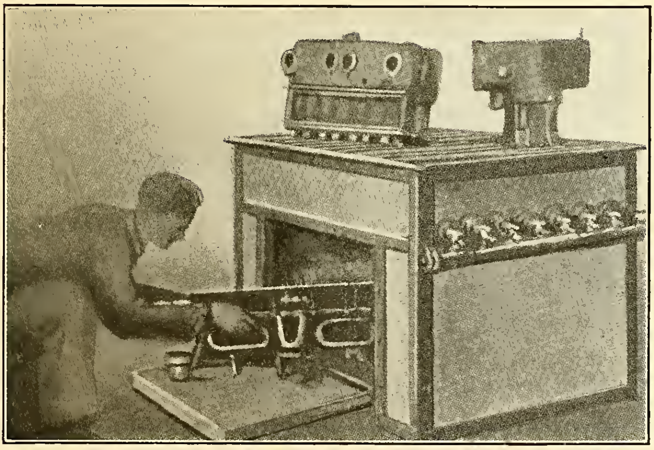


FIG. 121.—Showing the Slow Cooling Oven.

by the Geist Manufacturing Co., Atlantic City, N. J., and is known as the Wiederwax preheater. It has eight gas burners entering from each end and extending to the middle. This makes it possible to heat any section or all of the top, as desired. The top has parallel grate bars to support the work and the gas burners are buried in pieces of refractory, heat-retaining material, so that parts are heated with the use of a minimum amount of gas. After the welding is done, the work is placed in the oven underneath the heaters and slowly cooled.

When using this heater or welding at any time, the work should be covered with asbestos sheet as much as possible.

This concern also makes a floor-type of preheater for heavy work.

SUGGESTIONS REGARDING THE WELDING OF GRATINGS AND PULLEYS

S. W. Miller, of the Rochester Welding Works, writing in the "American Machinist" says:

It should be clearly understood by the welder that in a restrained weld, which is one entirely surrounded by metal, such

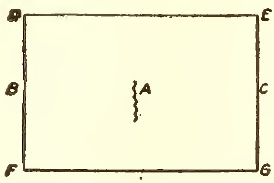


FIG. 122.—A Restrained Weld.

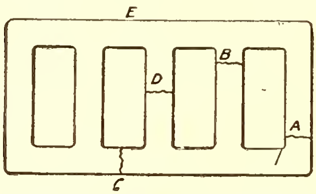


FIG. 123.—Grating to be Welded.

as a crack in the center of a plate, it is impossible to get rid of both strain and distortion; a moment's thought will make this clear. Such a crack is shown in Fig. 122. When crack *A* is welded the metal between *B* and *C* is heated hotter than that between *D* and *E*, and *F* and *G*, and, being soft, the expansion crushes it; so when cooling occurs, *B* to *C* contracts more than the rest of the plate, which either causes a crack, or leaves a tensile strain in the plate. It is true that the strain can be relieved by annealing, but that leaves a distortion of some kind; if the distance *BC* be the same as originally, the thickness along *BC* must become less, and vice versa.

If this is not clear, let the welder heat a spot in the center of a $\frac{1}{8}$-in. plate of steel, and see what happens.

In a partly restrained weld, such as Fig. 111, it is evident that the method of preheating described produces expansion of the part to be welded in such a way that the opening of the crack is *the same at all points in its length.* In other words, there is no variation in the width of the crack after expansion and before welding.

This is an important principle to be noted in expansion and contraction problems; it may be worded as follows: A crack must always be opened the same amount at every point in its length, if both strain and distortion are to be avoided.

Fig. 123 shows the condition of a grating when received at the welding shop. The quickest and cheapest way to weld this, if three men are available, is to double bevel all breaks; use three men to weld *A, B* and *D* at the same time, first on one side and then on the other; clamp the piece on a flat table to

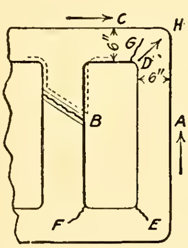


FIG. 124.—Result of Improper Heating.

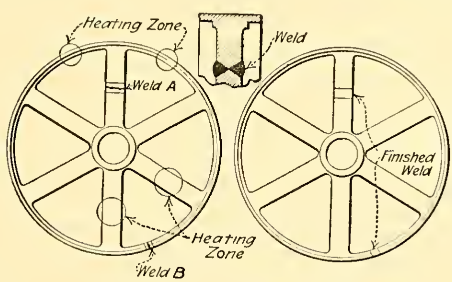


FIG. 125.—Welding a Broken Pulley.

keep it straight and let it cool. Then have one man heat at *E* with a torch, and let another weld at *C* as at the other points.

If only one man is at hand, he should weld *D* first; then, keeping bar *D* hot, weld *B;* next, keeping both *B* and *D* hot, weld *A;* allow the piece to cool, heat *E* and weld *C* as before.

This brings out the principle that one should *never finish* a weld in the *center* of a piece, unless it is *absolutely necessary;* always finish at the edge.

It will be seen that the method just described keeps the sides of the cracks parallel, and that if the proper allowance is made for contraction, there will be no strains left in the welded piece.

The matter may be made clearer by a study of Fig. 124, which indicates the result of improper heating. Heating the corner *H* for crack *B* will lengthen sides *A* and *C,* the resultant of these being in the direction of *D;* so that the upper part of crack *B* will lie as in the dotted lines, and after welding and cooling there will be strains at *E, F* and *G* which will surely cause cracks in service, if not at once.

With a smaller grating it is possible that there would be spring enough in the bars to avoid breakage; but there would be strains that could be avoided by other methods. The basic principle of all welding is to weld without having either strain or distortion in the finished piece.

With regard to pulley welding such as shown in Fig. 125, the rim should be heated on both sides of the broken spoke to lengthen the rim and pull the crack *A* open, and the spoke should be kept as cold as possible. Also all spokes should be welded from both sides.

The break at *B* should be opened by heating the spokes next to it so that when the crack is open enough, the edges of the break will be the same distance from the center; this of course means different amounts of heat in the two spokes.

AUTOMOBILE CYLINDER WORK

The next example is a block of two cylinders, broken as indicated in Fig. 126. The first break to be repaired is in the water jacket at *A*. The second break is on the flange at *B*, and the third is on the water jacket as shown at *C*. The fourth crack *D* is on the inside of the water jacket, necessitating the removal of part *E* by drilling in order to get at it.

To weld any of these cracks, except *B*, without preheating would break the casting from expansion when the flame was applied to it, and contraction when the weld cooled. The preheating in this case means the heating of the entire casting alike. To do this, build a furnace of firebrick, as shown at *F*. In order to give enough draft for the fire, the bottom bricks should be set about 1 in. apart. The cylinder block, with the cracks properly chipped and beveled, may then be placed on the first layer of brick and the walls built up around it. These walls should be so built as to allow about 6 in. between them and the cylinder. That is, there should be space enough allowed to turn the cylinder without knocking down the walls when ready to weld. About three or four shovelfuls of charcoal should be put around the cylinder and a little kerosene put on it and lighted. After the charcoal has become thoroughly lighted and the cylinder slightly heated, more charcoal should be added until half the casting is covered. Then a piece of sheet asbestos

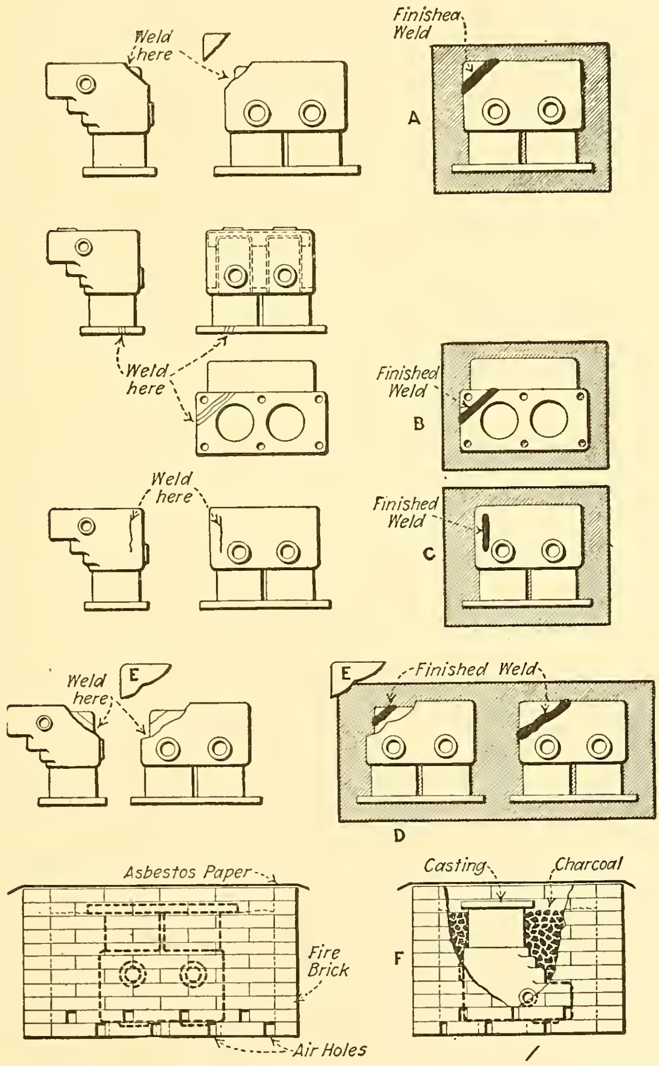


FIG. 126.—Broken Motor Cylinder Block and Preheating Furnace.

should be put over the top, and a few holes punched in it for draft. Where the break is bad, leave the cylinder alone until it reaches a dark red all over, then remove the asbestos and turn the cylinder so that the part to be welded first is uppermost. Then replace the asbestos and cut a hole in it so that the break can be reached with the torch and welding rod. Never take the cylinder out of the fire to weld.

In working on automobile cylinders it is usually unnecessary to preheat at all when welding lugs; in cases where it is necessary, only a very slight amount is needed—just enough so the cylinder cannot be handled without tongs.

Usually ordinary jacket cracks can be welded at much less than a red heat. In fact if a red heat is used, in most cases the cylinder bores will warp badly.

The important points in cylinder welding are a *uniform soaking* heat, not necessarily very high, welding on rising temperature, and slow cooling.

Never weld an important break in a cylinder block without about three hours slow preheating, never allowing the fire to die down. Then pack it in loose asbestos in the fire, to insure slow cooling. Of course, there are exceptional cases where the break is so bad that high preheating is needed.

Care must be taken not to let melted metal run down into the water jacket. Be sure to work out all dirt or scale, and do not leave any pinholes or blowholes. In order to prevent the bore of the cylinder from scaling, it should be coated with oil and a thin coating of graphite applied before the cylinder is placed in the furnace. After welding the graphite can be cleaned off with a piece of waste.

For crack *B*, the cylinder seldom needs to be preheated, as previously mentioned. The inner weld *C* is made the same as crack *A*. Crack *D*, being on the inside of the water jacket, is treated differently. A portion of the outer wall of the water jacket is removed by drilling, as previously mentioned. The inner weld is made, after which the removed portion is replaced and welded. In order to hold the piece in place while being welded a cast-iron rod may be welded to it to serve as a handle. After the weld is finished, this rod is cut off.

After the cylinder has been welded and cooled off, it should be tested to be sure that the weld is entirely tight. Where it is possible, this should be tested with water pressure. If it is not possible to do this, the water jacket should be filled with kerosene, because kerosene penetrates a crack or a pinhole faster than water.

In case any leaks are found, the metal should be chipped out at that point, placed in the fire, and rewelded exactly as before.

The next job, illustrated in Fig. 127, is typical of a large class. Work of this kind is usually in cast-iron, though occasionally of steel, or semi-steel. The piece shown is a cast-iron shear arm broken where the section is about 6 or 8 in. thick and 16 in. across. In preparing a casting of this size, the break is beveled at 60 deg. on each side, using a 12-lb. sledge and a handled chisel. It is then lined up and a preheating firebrick furnace built around the break, allowing sufficient space for the charcoal around the work. Then heat to a bright red well back from the break. Two welders should work on a job of this kind,

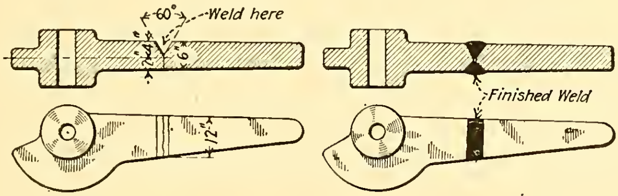


FIG. 127.—Broken and Welded Shear Arm.

each welding about half an hour or less, at a time. A large welding head, a long-handled torch and ½-in. welding rod are used. Two rods should be used, welded end to end. There should be plenty of rods and plenty of flux. There should also be a good supply of asbestos sheet and a bucket of water. The sheet is to keep in the heat and to protect the welders, and the water is to cool the torches. After the weld is completed on one side, and while the metal is still pretty hot, the casting is turned over. The movement will naturally destroy the firebrick furnace, which has to be rebuilt again, the casting heated up as before, and the weld made. In a job of this kind it is necessary to reinforce the weld on both sides. This reinforcing should be about ½ in. high. After the welding is all done, the piece is heated up to an even red heat all around the weld and allowed to cool very slowly.

In welding in or building up gear teeth, as shown in Fig.

128, it is seldom necessary to preheat. If the gear is a light one, say about 3 in. wide and with a rim depth of not over 1 in., the job can usually be done without preheating. However, preheating with some cheap fuel will, on large work, save the more expensive gases. In doing a job of this kind the greatest care must be taken to start properly. The work should be done so

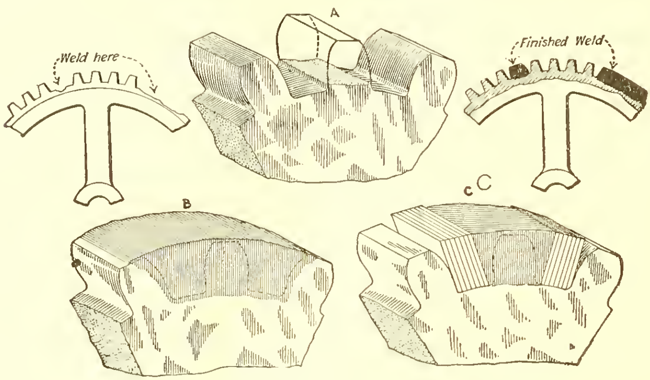


FIG. 128.—Method of Filling in Gear Teeth.

as to do away with as much machining as possible. Sometimes the tooth may be built up about as shown at *A* and finished by filing or otherwise. At other times it will be necessary to weld in on teeth each side of the one to be replaced, as shown at *B*. Again it may be possible to use carbon blocks and fill in as shown at *C*. In using blocks of this kind, care must be taken that there is ample room at the bottom for the root of the tooth being replaced.

CHAPTER XI

WELDING VARIOUS METALS AND THE FLUXES USED

The first property to be considered in welding various metals is the melting point. Gas-torch welding is the joining together of two metal parts by fusion at the line of contact and in order to secure a perfect weld it is necessary that each part be melted, and the molten metal allowed to flow together and harden in this state of mixture.

The approximate melting points and other properties of the metals and alloys commonly welded are given in Table XVI, taken from "Oxwelding and Cutting."

When metallic bodies are subjected to an increase in temperature they expand the rate of this expansion, being closely known for each degree of rise in temperature. When the temperature is lowered a reverse action takes place, the bodies contract and the volume and linear dimensions decrease. This has been explained to some extent in the previous chapter, and examples given to show the effects. Each metal has its own coefficient of expansion, which varies materially for the different metals. As seen from the table given, of the metals most commonly welded aluminum expands the most, bronze and brass next, then copper, steel, and iron. Aluminum expands almost twice as much as iron or steel.

Conductivity and Oxidation.—The conductivity of a metal is its property of transmitting heat throughout its mass. This property is not the same for all metals, and varies widely. It is commonly called thermal conductivity.

It can be seen that if one metal conducts or transmits the heat from the torch flame more rapidly than another, it is necessary that allowance be made as to the method of handling the job, the size of the torch, and the nature of the preheating equipment used.

In welding metals of high thermal conductivity it is necessary to use oversize tips—as in the case of copper where the

TABLE XVI.—PROPERTIES OF METALS COMMONLY WELDED

Metals	Weight Lb. Per Cu. In.	Tensile Strength Lb. Per Sq. In.	Coefficient of Linear Expansion Per Degree F	Specific Heat	Melting Point Degree F.	Relative Heat Conductivity Copper W1.00	Latent Heat of Fusion B.T.U's per Lb.
Cast	.0924	12000–14000	.0000123				
ALUMINUM				.2185	1215	.504	180
Drawn	.0967	25000–55000	.0000136				
Cast		18000–20000					
BRASS	Cu–60 Zn–40 .3036		00000957	.0939	1740	.204	
Drawn		40000–78000					
BRONZE	Cu–90 Sn–10 .3132	36000	.00000986		1650–1750	.735	
Cast		24000					
COPPER	.3186		.0000093	.09515	1982	1	77.9
Drawn		30000–60000					
White Cast		13000–22000			1922–2075		43.4
IRON	.2840			.1138		.152	124.2
Grey Cast		18000–29000	.00000556		2228–2786		59.4
WROUGHT IRON	.2779	50000–90000	.00000648	.1138	2732–2912	.156	
LEAD	.4108	1720–2050	.0000162	.0314	621	.076–083	9.66
NICKEL	.3179	54000	.0000071	.1086	2645 5	.14	122.4
Cast	.2479						
ZINC		5000–7000	.0000161	.0955	786	.303	40.6
Rolled	.2598						
Mild	.2834	55000	.0000063	.1165	2687	.139	
STEEL							36
Hard		78000		.1175	2370		

The Oxweld Co.

melting point is low and the conductivity high. However, too large a flame is bad, because the operator will not be able to correctly place the mass of molten metal. On sheet work the proper flame will melt the metal to a width about equal to the thickness of the sheet.

When welding heavy work the operator should be very careful not to blow a part of the molten metal on to the colder portions as it will make a defective weld at that point (called an "adhesion"). If this should occur, the flame should be played over this chilled portion until it is in fusion with the molten metal.

Certain metals oxidize more rapidly than others. Oxidation is the reaction produced by the combination of oxygen with a metal. The weld may become oxidized by contact with the oxygen in the air and by the presence of excess oxygen in the welding flame. An oxide has none of the metallic properties of the metal from which it is formed. When present in a weld it seriously weakens it and it is therefore very necessary that it be avoided as far as possible.

Some oxides are lighter than the metal itself, while others are heavier. Consequently, when a metal is reduced to a molten condition the oxide will either float on the surface of the liquid metal, remain suspended, or tend to sink toward the bottom.

The melting point of oxides is in some cases higher, and in others lower, than that of the original metals. This point must also be considered in attempting to eliminate oxide from a weld.

Some metals when molten also have the property of dissolving a portion of the oxide, the extent of this solution being dependent upon the metal itself. When this is the case the oxide is retained in solution until the metal hardens, in some cases separating and producing a weakened weld, in others being retained permanently.

Oxide may be dealt with in two ways. First, by taking means to prevent its formation, by the use of a neutral or reducing flame in the torch, or by the use of various cleaning fluxes; second, by eliminating the oxide after its formation with suitable fluxes, which either dissolve or float it off, or by mechanically removing it by the manipulation of the welding rod or a paddle made for this purpose.

The subject of oxidation is one of vital importance to the welder, one that he should study thoroughly in order to become familiar with all its forms. Oxidation is the cause of a great majority of defective welds.

There are also metals, that, when heated to the melting point, have the property of absorbing gases from the flame. When the metals cool, the gases are released. In a great many cases the release of the gases occurs at a time when the metal is not sufficiently fluid to allow them to pass to the air. Consequently, small bubbles or blowholes are incorporated in the weld. Then, too, in the welding of various metals the force of the torch flame causes the molten metal to flow back away from it. When the flame is withdrawn the molten metal returns—similar to the action of any other liquid. At such times the return of the molten metal may be so rapid that small quantities of the gases become entrapped and remain in the weld as blowholes. This is a very common occurrence in cast-iron welding.

In the case of the absorption of the gases by the hot and molten metal, the difficulties may be overcome by the use of proper protecting and cleaning fluxes and properly prepared welding rods.

In the case of the gases being entrapped by the molten metal, this may be overcome by "working out" the gas by means of the torch and welding rod.

Vaporization of Substances.—In the manufacture of metals substances are combined in amounts which determine the behavior and characteristics of the metal. In iron and steel there is a certain amount of carbon, silicon, manganese, phosphorus, sulphur, etc. While these substances may be present in only very small quantities, yet their elimination, or presence in excess, may materially affect the mechanical properties of the metal.

The high temperature of the welding flame may cause these substances to burn out or to volatilize. They can burn or oxidize directly in the oxygen of the atmosphere, in excess oxygen in the welding flame, or by the reduction of the oxide of the metal formed in melting.

In the working of brasses, bronzes, or an alloy in which zinc is present, it is commonly observed that the zinc vaporizes and passes off as heavy white fumes in the form of zinc oxide.

It can be seen that when this occurs the zinc content of the alloy is materially reduced, and consequently the resultant weld will not have the same mechanical and chemical properties as the original metal. Special fluxes are provided to prevent this; also, welding rods can be obtained which will either prevent the vaporization of the volatile substance or will replace it.

Separation of Elements.—Alloys are uniform mixtures of metals. The fusion of the different elements composing an alloy is carried out at a certain fixed temperature. In the welding of metals of different kinds, it has been noted that when some of these alloys have been heated to the high temperatures produced by the welding flame various substances separate or segregate and that it is impossible to secure a uniform weld.

This segregation occurs quite frequently under the torch flame and also occurs in the manufacture of the metal. Under these conditions the difficulty of welding some alloys can be readily seen.

Welding Various Metals.—With the foregoing facts and suggestions in mind we will now take up the various metals most frequently welded, and give directions that will apply in their special cases. The composition of various fluxes will also be given, but it should be remembered that the different accessory concerns can supply far more satisfactory fluxes than can be made in small lots by the individual user, and the welder should, where possible, buy the fluxes needed and apply them according to directions. This also applies to welding rods which should be bought from reliable concerns for certain specified jobs. For emergency work, where the proper rods are not available scrap material or wire may be used, but it is not good practice. A first-class welder who cares for his work and his reputation will use rods of the proper chemical composition for the work he has to do. For this purpose he should buy his rods from firms of established reputation, who are not afraid to advertise their output.

Welding Aluminum.—Aluminum parts to be welded may be divided into two classes—those made of drawn or rolled aluminum and those which are cast.

Rolled aluminum is usually 98 per cent pure or better, the main impurities being silicon and iron. Aluminum as pure as this is seldom used for castings, since its strength is considerably less than that of various alloys. Zinc in amounts ranging from 5 to 25 per cent, but usually about 10 per cent, was often used in the past, but the alloy was so brittle just below solidification that a large number of castings were defective owing to shrinkage cracks. A copper alloy is now more commonly used, the copper content being less than 15 per cent, 7 per cent probably being the favorite. This is not so strong at ordinary temperatures as the zinc alloy, but it does not have such a tendency to crack. This makes it much better for welding as well as for casting, especially on complicated work.

Aluminum oxidizes easily in the air, especially at high temperatures, and in the latter condition the oxide coating is quite thick. This oxide melts at a much higher temperature (5000 deg. F.) than aluminum (1215 deg. F.) and as the oxide is of greater specific gravity (heavier) than molten aluminum, it will sink down into the metal when welding unless it is removed in some way. As the oxide is very persistant to the action of any acid or alkali, even at a high temperature, any flux used must of necessity be drastic in action and if carelessly used, exceedingly injurious to the aluminum weld. On this account any flux should be used with caution and any surplus removed as soon as possible.

Table XVII.—Fluxes for Welding Aluminum

	Formula Numbers						
	1	2	3	4	5	6	7*
Chemicals	%	%	%	%	%	%	%
Sodium Chloride	30.	...	12.5	16.	17.	6.5	30.
Potassium Chloride	45.	33.3	62.7	79.	83.	56.	45.
Lithium Chloride	15.	33.3	20.8	...	...	23.5	15.
Sodium Fluoride	...	33.3	...	...	...	...	...
Potassium Fluoride	7.	...	...	...	...	...	7.
Sodium Bisulphate	3.	...	...	...	...	...	...
Potassium Bisulphate	...	...	4.	...	...	...	3.
Sodium Sulphate	...	...	...	...	...	4.	...
Potassium Sulphate	...	...	...	5.	...	...	...
Aluminum Sodium Fluoride	...	...	...	...	...	10.	...

* Recommended by the French Laboratories of the Autogenous Welding Association.

A flux is generally used in welding sheet aluminum where the puddling method cannot well be employed. More divergence must be allowed than for iron. Fluxes are usually composed of alkaline fluorides, chorides or other combinations as shown in Table XVII. However, these and other flux mixtures are only given for reference purposes, and it cannot be too strongly urged that all welders buy the fluxes used and follow directions in each case.

Where a flux is used in welding aluminum, the edges and adjacent surfaces should be well scraped and cleaned as the flux is only intended to eliminate the oxide and not grease and dirt. In welding heavy sheets the edges should be beveled and in light ones the welding will be aided by flanging the edges about $^1/_{16}$ in.

Aluminum castings are handled a little differently from sheets or plates. As previously mentioned castings are of different composition. Since the metal has a low melting point, high conductivity, and becomes rather fragile previous to fusion, preheating and cooling must be carried out very carefully. The average aluminum casting is somewhat complicated in its design, hence the necessity of skillfulness in carrying it through the preliminary heating period.

The use of a flux on aluminum castings has been abandoned by the majority of welders. In place of it they break down and remove the oxide by means of a paddle, which is also used to smooth off the surface of the weld after it is completed. In many cases it is an advantage when working on castings, not to bevel the edges.

In most cases aluminum articles should be preheated to some extent before welding. In certain cases the playing of the secondary flame on the object will be sufficient; in others a more thorough treatment is required, such as charcoal or coke. On the regular run of castings it is safest to preheat to about 500 or 600 deg. F., which on iron would correspond to a low red heat. In the case of a broken lug or piece of a flange, it is often really dangerous to preheat as it may cause the whole piece to collapse or distort. The beginner should also be very careful about shifting or turning a hot aluminum casting as it may get out of shape or crumble into pieces. Since the metal is so apt to crumble when hot it is advisable for the beginner, and often the expert, to back up the parts. This may be done by molding a backing out of asbestos fiber 2 parts and plaster of paris 1 part, made into a thick paste with water. Have this mold about an inch thick and perfectly dry before setting in place. Fireclay may also be used in many cases to back up or support fragile parts. When the weld is completed the casting should be allowed to cool very slowly and evenly. The iron puddling rod should not be allowed to get too hot or oxide of iron will be formed and scale off, making a defective weld.

Only a small amount of metal from the welding rod should be added at a time and this must be thoroughly stirred or "puddled" until a pool is formed that insures perfect fusion with the surrounding parts. Use the puddling rod to scrape off surplus metal while it is in a pasty condition. The beginner will find it a little difficult to manipulate the puddling and the welding rods alternately with the same hand but this becomes a habit with practice, and many do this by holding them between the fingers so that neither needs to be laid down. The property of conducting heat is greater in aluminum than in iron, but as the melting point is much lower, about the same size torch tip is used as for cast iron of corresponding thickness.

Filling a Large Hole.—The *Journal of Acetylene Welding* says that when the filling of a large hole is required a chill of galvanized iron is provided, backing up the hole and welding against this when filling the hole with aluminum. Galvanized iron is preferable to any other material, such as tin or iron, since it peels away from the aluminum quite readily, and can therefore be easily removed after the weld has been completed. This is undoubtedly due to the zinc content of the galvanizing composition.

The chief value of the use of the chill is that it causes the filler to cool and harden quickly, thereby preventing it from contracting after the weld is finished. It also prevents the heat of the weld from spreading, which might cause the job to crack back.

The chill causes the added metal to cool almost as fast as it is connected to the edge of the break. After the weld has been finished and cooled, the chill can be removed by gently prying it away from the weld by means of a cold chisel.

Brass and Bronze.—The composition of brasses and bronzes varies so widely that it is not good for a welder to use welding rods of the same composition for the general run of repair work. However, rods of Tobin bronze or manganese bronze are very satisfactory for all-round work. Where it is important to match the color of the weld with that of the surrounding metal it is necessary to use special rods of practically the same composition as the welded metal, and also to use extra care with the torch. This latter will be better understood when the welder knows that several of the alloys such as zinc, tin, etc., used with copper to make brass or bronze, volatilize easily and in so doing change the character of the metal. These metals should be prepared in the same way as any other. They must be so placed as to not move during the welding. Fireclay may be used to back up pieces in danger of collapse. The end of the flame cone should not touch the metal, but should be kept some distance above it. If a white smoke rises, or, as in the case of bronze, the metal bubbles, remove the flame, as it indicates that too much heat is being used and some of the elements are passing off in vapor. Do not breathe this vapor as it is poisonous. It is desirable to use a tip about the same size as for cast iron. A flux should be used though not too liberally. Calcined borax is good. Boracic acid is also good and, if used, may be applied by dipping the hot rod into the powder from time to time. The principal points to watch are not to heat too hot; do not move the parts until well cooled; do not use too much flux, and be sure to guard against caving in or distortion of the work by properly supporting it previous to heating. If the metal is porous on cooling it is a sure sign that too high a heat was used.

Cast Iron.—When cast iron is molten it oxidizes very rapidly. The oxide which begins to form at a bright red heat, melts at a temperature of 2400 to 2450 deg. F. Since the metal itself melts at a temperature several hundred degrees below this, it can be seen that the oxide will not be melted at the same time as the metal. In order to break the oxide down and allow the metal to flow together a flux must be used. A properly formulated flux will dissolve the oxide and float it to the surface, so that it may be removed by scraping the molten surface with the end of the welding rod. The welder should tap the end against something to free it from oxide before continuing to add it to the weld.

A good flux for use in welding cast iron may be made up of equal parts of carbonate of soda (washing soda) and bicarbonate of soda (baking soda). There is practically no advantage in using the pure chemicals in this case as the commercial product, which may be obtained at the grocery store, will do as well as any. The two sodas should be thoroughly mixed, however, which may be done by running them through an old coffee mill several times, or thoroughly shaking and sifting in a sieve. The flux is applied, as in most other cases, by dipping the hot welding rod into it.

Cast iron is quite fluid when melted. For this reason it offers considerable difficulty where vertical or overhead welding is attempted. Also its fluidity causes it to entrap gases, dirt, and oxide. These may be removed by proper manipulation of the torch and welding rod. As the molten iron can be forced ahead of the weld very easily, adhesion to the cold metal will result, if the welding is not watched carefully.

The silicon will volatilize to some extent in the molten metal and the lowering of the amount of this constituent will seriously increase the hardness of the metal. In order to compensate for this loss, a welding rod is used that contains from 2.75 per cent to 3.5 per cent silicon. The other substances such as sulphur, manganese, and phosphorus should be kept within rigid limits. The welding rod should be soundly cast, free from dirt, sand, scale, rust, etc.

The welding flame should always be neutral. The flame should be applied to the weld at such an angle that the metal will not be blown ahead. Inasmuch as the metal is quite fluid when molten, the welding is carried on in a series of overlapping "pools" or puddles. The welding rod is applied by placing it in these pools and playing the flame around it. The welding is aided by continually "working" the rod in the weld in order that blowholes, dirt, scale, etc., will be forced out.

The central jet of the flame should never impinge on the molten metal. It should be held $1/8$ in. to $3/16$ in. from it. Occasionally it is necessary to remove a blowhole, in which case the hole is burnt out with the flame and then the metal is worked over with the welding rod. The working over of a weld should be avoided unless it is absolutely necessary. If it is necessary to do this the welding rod should be used always, for otherwise a portion of the silicon will be lost.

When the weld is finished and it is still hot, the accumulation of scale, dirt, flux, etc., on the surface should be removed by scraping with a coarse file or other tool. This is a superficial coating that, when cold, is very hard.

As soft welds are nearly always desired, the casting should be cooled slowly and evenly. Where the work is complicated or of heavy section, it is by all means best to reheat it to a good red heat and then allow is to cool slowly. In some cases where charcoal has been used it is sufficient to allow the casting to cool in the preheating fire, without the additional reheating.

Cast Iron to Steel.—To weld cast iron to steel, cast-iron rods must be used as the welding material. The steel must be heated to the melting point first, as cast iron melts at a lower temperature. A very little flux should be used.

Copper.—Copper usually is produced in an almost pure homogeneous form. The impurities are present in small amounts and are not affected materially by fusion. Copper is a good conductor of heat, and is very tough, ductile, and malleable.

From these properties it would appear that it is easily welded. Unfortunately this is not true. There are few welders skilled in the handling of this metal.

Copper has two very pronounced properties under the welding flame. It absorbs gases very readily, notably carbon monoxide and hydrogen. These are released when the metal begins to solidify, with the result that they remain entrapped, producing a porous structure.

Copper oxidizes very rapidly when undergoing fusion. The molten metal has the property of dissolving the oxide thus formed. It will take up such large quantities of it that the mechanical properties of the weld will be affected. In addition to these two peculiarities the tensile strength of copper decreases rapidly as the temperature is raised, particularly from 500 deg. F. upward. The effect of temperature is so severe that at 900 deg. F. the tensile strength is only 40 per cent of that at atmospheric temperatures.

Because of this weakening under heat, the strains resulting from contraction in the weld during cooling must be carefully dissipated, otherwise the metal in the weld or adjacent to it will fail.

A neutral flame should always be applied in welding this metal. If an excess of acetylene is used the products of combustion are richer in those gases which are easily absorbed. If an oxidizing flame is used, the weld becomes saturated with the oxide.

A larger size torch tip than the melting point of copper indicates is used because of the high thermal conductivity. Where possible, auxiliary heating, such as air-gas flames and charcoal fires, should be employed. This is done not only from the standpoint of economy, but it also aids greatly in the success of the weld.

The torch flame should play on the weld in a vertical direction. The metal when molten is quite fluid, and for this reason if the torch were applied at an angle the metal would be blown ahead, producing adhesion. Also, by applying the torch vertically the molten metal is protected from the oxygen of the atmosphere by means of the enveloping flame.

Copper, if properly prepared and free from grease or dirt, does not need a flux.

The factor that contributes most to the successful welding of copper is the use of a properly formulated welding rod. Such a rod will overcome, to a great extent, both the absorption of gases and the solution of the oxide. It is not considered practical to remove the oxide in the weld by means of a flux, because it is dissolved in the metal. A welding rod is needed that has combined with it a reducing or deoxidizing agent. The reducing agent has a greater affinity for oxygen than copper, hence it combines with it and brings it to the surface in a fluid form. This material acts as a glaze or protecting coating for the molten metal beneath it, with the result that it tends to retard the absorption of the gases.

Several materials, when added to a pure copper rod, have proved to be beneficial. The most prominent element at this time is phosphorus. It should be present in amounts not over 1.0 per cent; otherwise the metal will be pasty and the weld will be weakened.

Newly welded copper has only the strength of cast copper, but after welding, the grain of the weld and the metal adjacent can be improved by hammering at a low heat.

Copper to Steel.—If it is desired to weld copper to steel, heat the steel to a welding heat, then place the copper in contact. The metals will then fuse together. Take away the flame as soon as the copper flows properly. No flux is needed.

Lead.—Lead can be readily welded. The process, however, is usually known as "lead burning." The gas torch provides a means of doing this work quickly and at a low cost. Skill in the manipulation of the torch is necessary, particularly on vertical seams. A light torch should be used. When welding sheets or plates, proceed as in lead burning by other processes.

The burned joint on a lead or block tin pipe line is not only a neat and permanent joint, but is all lead, and a block tin line is all block tin. The joints are fused together with the addition of enough metal of the same kind. If, for instance, a lead pipe line is to carry acid, the burned joints contain no solder which could be attacked by the acid.

In preparing lead pipe for welding the two pipe ends are scraped clean for about an inch back, and are tapered slightly at the edges. It is not necessary to drive one pipe into the other. The two ends are merely placed in contact and welded or "burned" with the addition of more lead to fill up the joint. No flux, no grease and no "wiping" of any kind is needed.

Malleable Iron.—The manufacture of malleable iron has made enormous progress during the last few years, and while formerly malleable iron was really an unknown quantity and might contain different mixtures, from white iron to hard steel, in the same casting, a great uniformity is now obtainable by adherence to strictly scientific methods.

The Associated Manufacturers of Malleable Iron has set a standard of quality, to which all its members must adhere rigidly and castings procured from one of its members may be relied on to consist of a uniform and thoroughly high-class product.

While formerly the welding of malleable iron was considered almost impracticable on account of the different structures in one and the same casting, it may now be welded with almost a certainty of success, if the casting was made in accordance with the rules of the association.

The break on malleable iron is prepared exactly the same as for any welding job, cleanliness in this instance being especially desirable, since dirt tends to weaken the weld considerably. Allowance should be made for the effects of expansion and contraction; malleable iron is less liable to break than cast iron, since it is ductile, but will be distorted unless such provisions are made. Use for flux the same powder used for brass—that is: borax or a purchased mixture.

As with cast iron, do not let the end of the cone touch the casting, but hold it just a little distance away. Watch the metal carefully and as soon as the metal begins to melt, add the filling rod, either Norway iron or malleable rod of the same grade as the casting.

However, not all malleable castings are of the high degree just described. They were originally white cast iron, very brittle and hard. By heat-treatment the carbon content is changed, and instead of the brittle casting, it becomes ductile, fairly soft and changes to a darker color. Just how far into the body of the metal this change penetrates depends upon the size of the casting and the length of the heat-treatment, so that a malleable casting, as it is generally called, may be steel on the surface, a semi-steel part way through and white cast iron at the core.

Very small castings sometimes are steel all the way through and we may weld them without flux, using Norway iron or mild steel as the welding rod.

In nearly all cases, however, it will be found that the casting, if not made to association specifications, is composed of different metals—if the break is examined, we can tell this by the different colors. It is obvious that such a casting cannot be welded, since it would be extremely difficult to determine just where one metal left off and another began. The practice of using cast iron as a welding rod on malleable castings is not a good one, since the bond is very brittle and in all cases where strength is desired we would better use manganese or Tobin bronze—in this way securing a brazed joint instead of a welded one, of a different color than the casting but with the factor of strength a big one.

Watch the metal carefully and when the spot the flame is playing upon reaches a bright red heat, bring the bronze welding rod, which has previously picked up some borax, down upon this section, being careful that the cone does not come directly in contact with the bronze rod. Bronze melts at a lower temperature than malleable iron and with the iron at a bright red heat, and with plenty of flux used, it will be found that the bronze attaches itself to the iron. We must not, however *melt* any portion of the malleable iron and we must not play the cone directly on the iron or on the bronze.

Monel Metal.—Technically, monel metal is an alloy of nickel and copper, containing about 67 per cent nickel, 28 per cent copper, and 5 per cent of other elements. This remaining 5 per cent consists partly of iron from the original ore and partly of manganese, silicon, and carbon introduced in the process of refining. It contains no zinc or aluminum. The alloy can be machined, forged, soldered and welded, both electrically and by the gas torch. In the automobile industry it is used for float valves in carburetors because it combines hardness with non-corrodibility. Borax or boracic acid may be used as a flux.

Nickel.—Nickel melts at 2600 deg. F. and when melted has the property of absorbing large amounts of various gases, especially oxygen. The gases so absorbed remain when the metal cools, making it very porous. Nickel has also a great affinity for sulphur. It is often stated that nickel cannot be welded, but this is an error, although it is an extremely difficult metal to weld satisfactorily. Anodes used in nickel plating may be fused together without flux as the blowholes do not affect the conductivity to any appreciable extent. However, where a weld is wanted free from blowholes, the nickel pieces should be laid on a heavy plate heated bright red or white, and the nickel heated to a bright white with the gas torch. The joint should then be carefully hammered with a light hammer. Previous to heating the nickel should be freed from grease or oil and scraped well back from the weld.

Steel.—Steel welding on a commercial scale should never be attempted until after the operator has proved to his own satisfaction that the weld is strong by welding together mild steel plates $\frac{1}{8}$ to $\frac{1}{4}$ in., sawing them through the weld to make sure that the material is really bonded and testing them by bending back and forth in a vise.

Steel melts at 2500 to 2700 deg. F. When molten it is not extremely fluid. At dull red heat it begins to oxidize rapidly. The oxide, which melts at a temperature of several hundred degrees below that of the metal, remains at the surface and can be easily removed. A flux is not necessary, although some welders use a little borax. Close attention must be paid to the removal of the oxide, however, for its presence is very harmful.

It is a common fault to have layers of oxide in the weld, which cause a laminated structure that weakens it.

Steel does not melt rapidly. It gradually comes to fusion, confined to small areas. Because of this, the weld is made up of small overlapping layers. The strength of the weld depends greatly on the thorough bonding of these layers to each other and to the beveled edges of the piece being welded. It is a common fault to force the metal ahead of the welding area and allow it to adhere to the cold sides of the beveled edges.

A welding rod of over 99 per cent pure iron wire is commonly used. Occasionally a nickel steel rod is used with good results on such work as crankshafts. A mild-steel rod is particularly satisfactory on steel castings.

Thickness of Steel	Diameter of Welding Rod
1/8 in.	1/16 in.
1/4 in. to 3/16 in.	1/8 in.
1/4 in. to 3/8 in.	3/16 in.
1/2 in. and up	1/4 in.

Steel is very sensitive to the welding flame. An excess of acetylene tends to carbonize the metal; an excess of oxygen tends to oxidize. Therefore, a neutral flame should always be used and should be tested frequently in order that it be kept in proper adjustment.

Failures due to expansion and contraction are not numerous, because of the toughness and strength of the metal. If expansion and contraction are not properly taken care of, however, warping and buckling will surely take place, and internal strains will exist in the weld.

These can be avoided by properly setting up the work and with proper preheating methods.

The strength of a steel weld can be improved by mechanical treatment. Hammering is the most common method employed. After the welding has been completed, the entire weld should be heated to a bright red heat, and the hammering carried on at this temperature. If the hammering is done at a lower temperature, the weld will be weakened instead of strengthened.

The welder should always keep in mind that the higher the percentage of carbon in the steel the greater is the danger of burning the metal, with its consequent weakening effect.

Steel castings should be handled in a manner similar to cast iron. They may be preheated and prepared in the same way. Cast steel as a rule has a percentage of carbon between that in mild steel and gray cast iron. As a filler, good results will be obtained if cast bars of the same material are used. If not available, use vanadium steel or Norway iron filler.

While little work is done in welding high carbon or hard steel, the following instructions are given as a guide to the operator in case of necessity. Parts should be prepared for welding as for wrought iron or steel. Use a larger tip than for the same thickness of mild steel. For filling material where the parts are to be hardened, use ordinary drill rod. Drill rod is a hard steel which is used by tool manufacturers in the manufacture of drills, reamers, etc. Ordinary mild steel cannot be tempered and this is often necessary when high carbon or hard steel parts have to be welded. Employ cast-iron flux. Execute the weld very rapidly as there is a tendency for the metal to burn easily and also to decarbonize; that is, to burn out the carbon, leaving the metal in poor condition. A very slight excess of acetylene in the welding flame may be advantageous.

To weld high-speed steel to ordinary machine steel, the end of the high-speed steel to be welded must first be heavily coated with soft special iron. It can then be welded to ordinary machine steel without burning, but it takes an experienced welder to make a good weld of this kind.

Special Steels.—There are many special or alloy steels used in the metal industry. The operator is often called upon to attempt welding on these. Many automobile and locomotive parts are made from special high-carbon steels, and often these castings or forgings undergo, during manufacture, special heat-treatments which are in many cases more or less of a secret process. It will be appreciated that welding with a high-temperature flame must necessarily counteract the effects that were produced by the heat-treatments, consequently, to make the part efficient it is essential that after welding, the piece be properly heat-treated by an operator skilled in such work. The services of such a man are rarely available, therefore, the results obtained when welding high-carbon alloy steels will be uncertain. Fortunately, however, many of the alloy steels used in practice are not high carbon and can be welded satisfactorily.

Manganese Steel (low carbon) is welded quite readily. The manganese acts as a deoxidizing agent; that is, it counteracts the effect of burning the metal. If possible, use a filling material of the same composition as the part welded. If this cannot be obtained use Norway iron.

Nickel Steel (low carbon) can be welded without difficulty in exactly the same way as mild steel, but nickel-steel filling rod must be used.

Vanadium Steel (low carbon)—This is probably the most commonly used steel alloy. Very fortunately it is extremely easy to weld, and flows much more readily than ordinary mild steel. Weld as mild steel, but use vanadium-steel filler.

Chrome Steel is in the class of mild or low-carbon steel and can be welded readily. Weld as mild steel. Use a chrome-steel filler. Many chrome steels, however, are in the high-carbon or hard-steel class.

Wrought Iron may be easily welded without a flux though a little borax or other flux is sometimes advisable. The same general rules apply as for mild steel.

Galvanized Iron cannot be welded, since the iron is covered with, and to a greater or less extent impregnated with, a lower melting metal.

German Silver, in many cases, is considered unweldable, due to its absorption of gases. For practically all commercial purposes, it may be bonded, using the same flux as for brass and a strip of German silver for the welding rod. Especial care must be given to expansion and contraction.

White Metal Castings used for die molded purposes usually are composed of aluminum, tin and zinc in varying proportions, but nearly always with the lower melting metals in the larger proportion. While the castings have a good deal the same appearance as aluminum, they are considerably heavier. They may be considered unweldable.

Silver acts very similar to nickel and should be welded in the same way by heating and hammering. However, soldering usually answers all purposes.

Gold welds very easily and the pure melting process is all that is needed.

CHAPTER XII

EXAMPLES OF WELDING JOBS

The way a crack to be welded is V'd out or plates are beveled, has already been outlined, but it will be well to elaborate a little on the methods of doing this work. On steel or wrought iron, the beveling may be done with a gas cutting torch. On

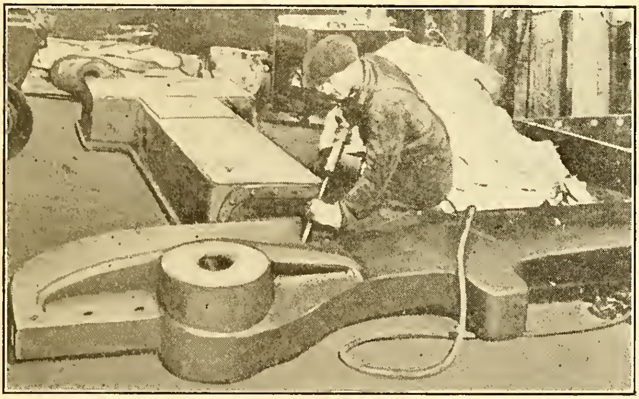


Fig. 129.—An Air Chisel May be Used Either for Grooving or Finishing.

other metals, such as aluminum or cast iron, the gas cutting torch cannot be used, although the metal may be roughly melted away. Sometimes the work is of such a nature that the bevel may be ground, either with a stationary or a portable electric grinding machine. On cast iron, a sledge and a handled chisel is often the cheapest and quickest way, and in nearly every case it is superior to melting the metal away with a gas torch.

A very satisfactory beveling tool for all-round shop work, is an electric or a pneumatic chisel such as shown in use in Fig. 129. This may also be used for taking off surplus metal after welding, although a portable electric grinding machine is usually preferable.

On work like the propeller blade shown in Fig. 130, the slots may be cut with a saw or a milling cutter and the pieces

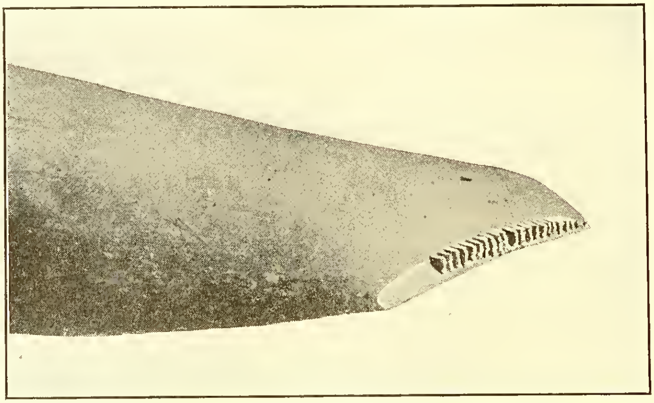


Fig. 130.—Propeller Blade Partly Beveled for Welding.

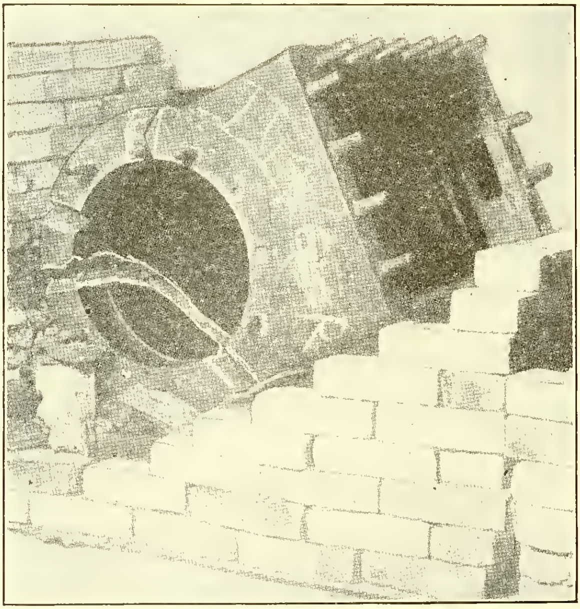


Fig. 131.—Cylinder Grooved Out for Welding.

left may be knocked off with a hammer. This bevel might also be chipped, ground or melted off, as the occasion or equipment at hand demanded or made advisable.

An engine cylinder grooved out and ready for preheating is shown in Fig. 131. In a case of this kind the grooving may

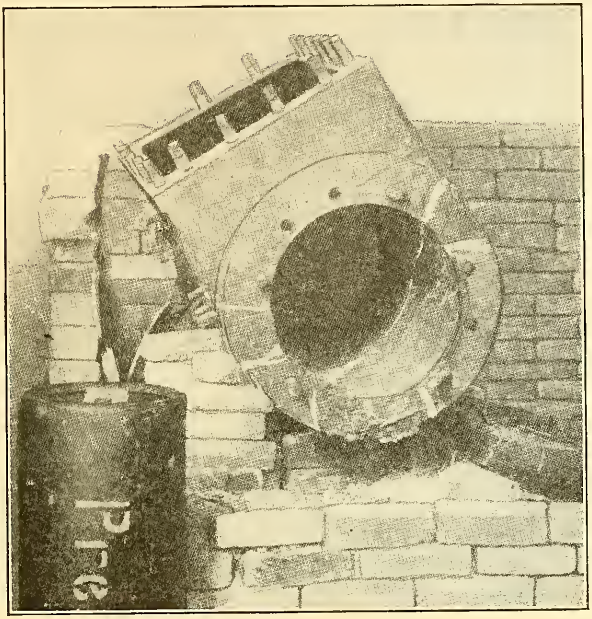


FIG. 132.—The Cylinder as Welded.

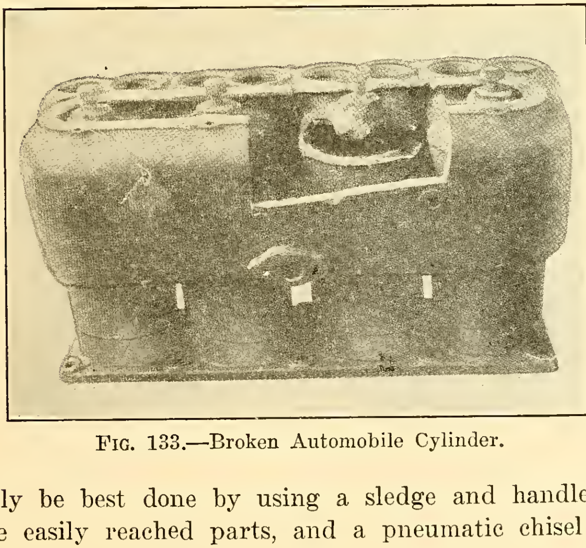


FIG. 133.—Broken Automobile Cylinder.

probably be best done by using a sledge and handled chisel for the easily reached parts, and a pneumatic chisel for the rest. However, this largely depends on the size of the work and the judgment of the workman. Fig. 132 shows the cylinder welded and ready to be smoothed up.

A badly broken four-cylinder block is shown in Fig. 133 and the repair in Fig. 134. The actual cost to weld this job was less than five dollars. The method of procedure has been previously described.

In Fig. 135 a welder is shown working on a job while a helper is tending to the preheating of another. The method of welding through a hole in a large sheet of asbestos not only keeps the heat in, but protects the operator as well.

In Fig. 136 is shown a badly broken aluminum upper crank

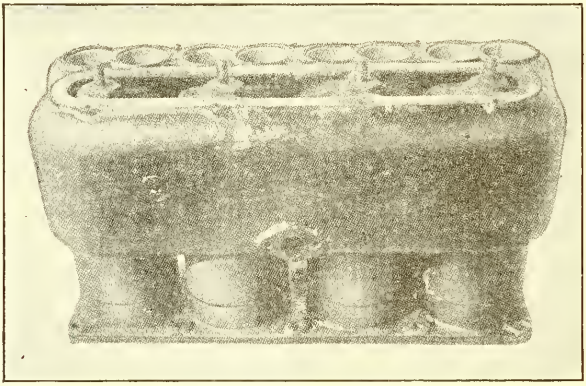


Fig. 134.—The Finished Weld.

case and the repair. Work of this kind often comes to the shop that caters to the automobile trade. Another repair of interest to the garage man is shown in Fig. 137. The cost of putting in a new frame in this 5-ton truck would have been at least $600. The weld was finished and guaranteed for $25.

The welding of a tire for a 15-ton truck wheel, 10 in. wide by $2\frac{3}{4}$ in. thick, is shown in Fig. 138. The preheating was done in a large blacksmith's forge. In this connection, the welder must get out of his head a very common idea that preheating is only needed to take care of expansion and contraction. It is just as valuable in its way, for saving expensive welding gas. This is the reason for preheating the large tire, since its shape and nature precludes any expansion of contraction troubles provided the welder has even ordinary skill.

Fig. 135.—Welding and Preheating.

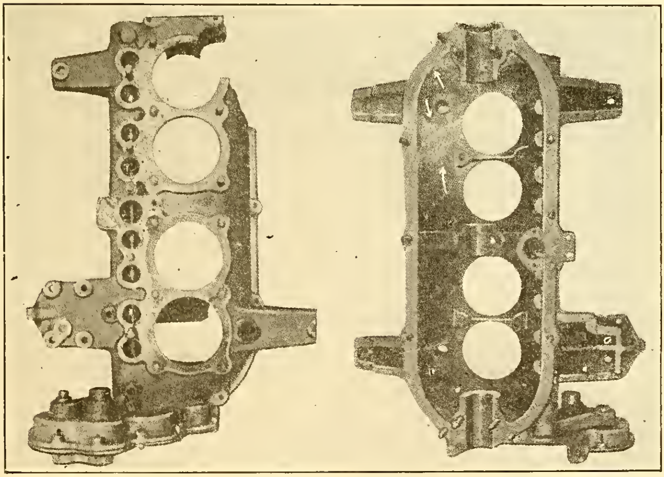


Fig. 136.—Broken and Repaired Aluminum Crank Case.

In the example shown in Fig. 139, which is a kettle 5 ft. 6 in. in diameter and $1\frac{1}{8}$ in. thick, preheating is absolutely necessary in order to take care of the expansion and contraction. The crack was around the outlet and was 22 in. long. The

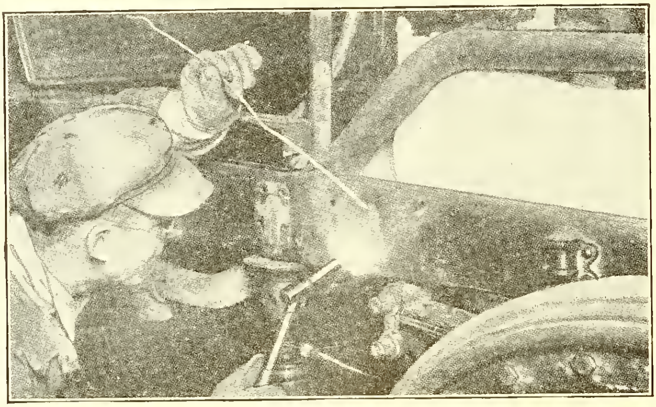


FIG. 137.—Welding Frame of 5-Ton Motor Truck.

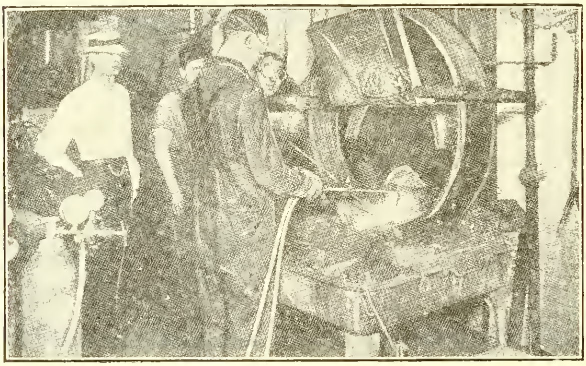


FIG. 138.—Preheating and Welding Large Truck Tire.

welding time was 1 hr. 45 min., in addition to the time it took to preheat the kettle the required amount.

The welding of a 7-in. crankshaft for a 200-hp. internal-combustion engine is shown in Fig. 140. The finished weld is shown in the insert. The work was finished and the crankshaft put back in service inside of 30 hr. The section of the shaft added was oversize to permit machining for alignment. Preheating in this case saved a considerable amount of welding gas. The improvised furnace also made slow cooling possible.

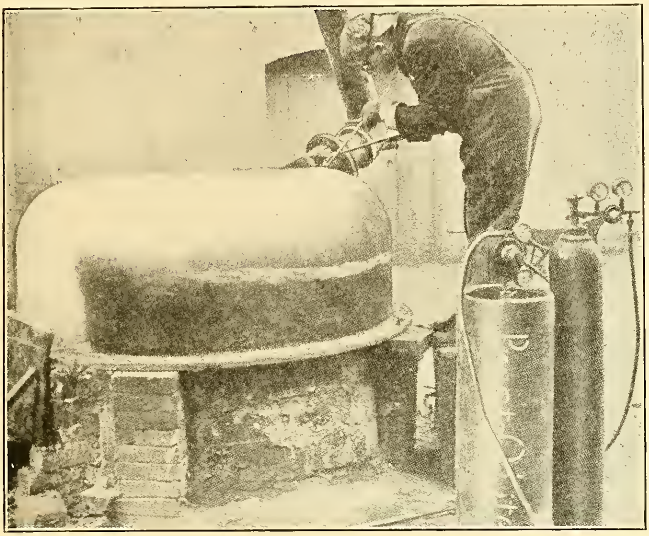


Fig. 139.—Preheating and Welding a Large Kettle.

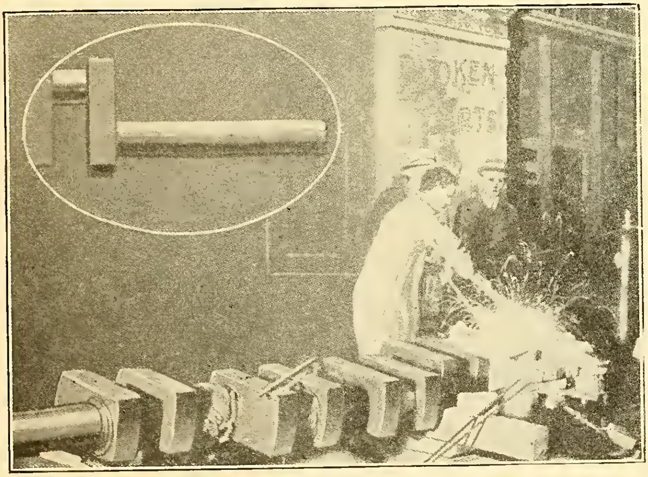


Fig. 140.—Welding a Large Crankshaft.

Welding Broken Machine Tools.—The planing-machine bed, shown in Fig. 141, was cracked through on one side close to the housing boss. The job was finished without serious disalignment, but under ordinary circumstances such a repair would not be recommended unless means were at hand for refinishing the ways and possibly other machined surfaces. As a war-emergency

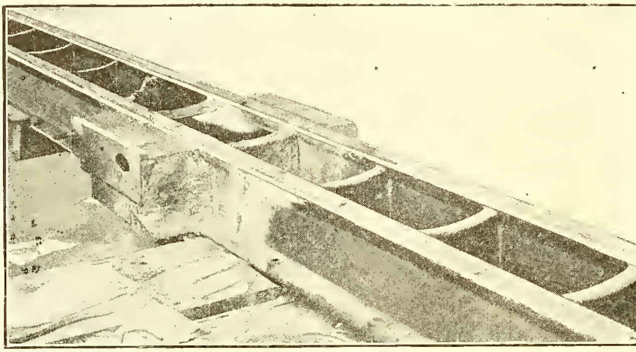


FIG. 141.—Weld on Large Planing-Machine Bed.

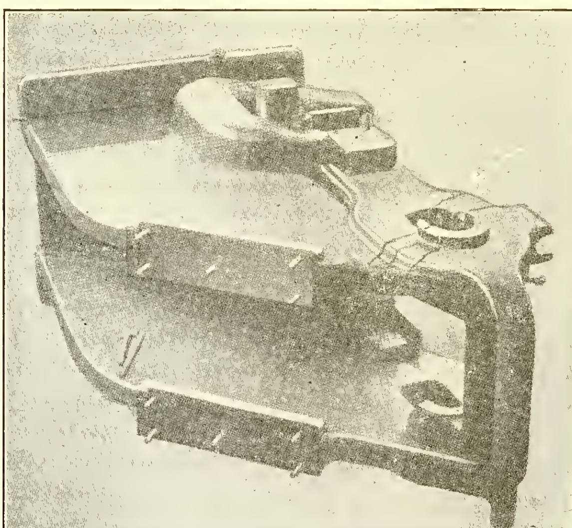


FIG. 142.—Broken Punch-Press Frame.

repair, however, it proved satisfactory. The redemption of a similar casting, damaged while still in the rough, might also be a money-saving proposition in some cases.

The punch-press frame shown in Fig. 142, outside of its

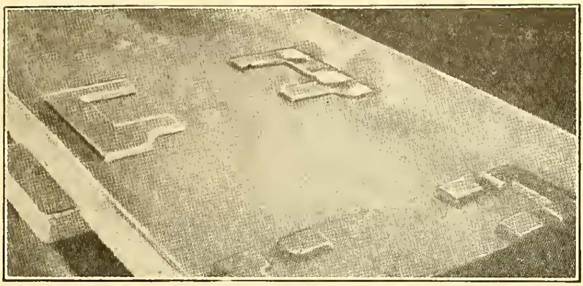


Fig. 143.—Welded Blowholes in Lathe Pan.

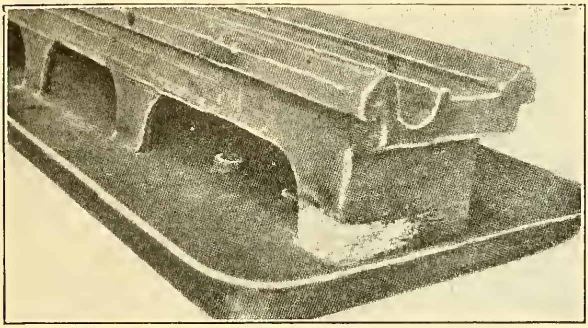


Fig. 144.—Welded Crack in Lathe Bed.

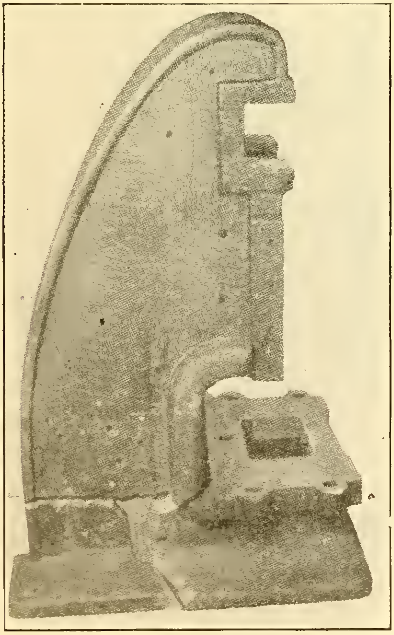


Fig. 145.—Broken Press Frame with Breaks Beveled.

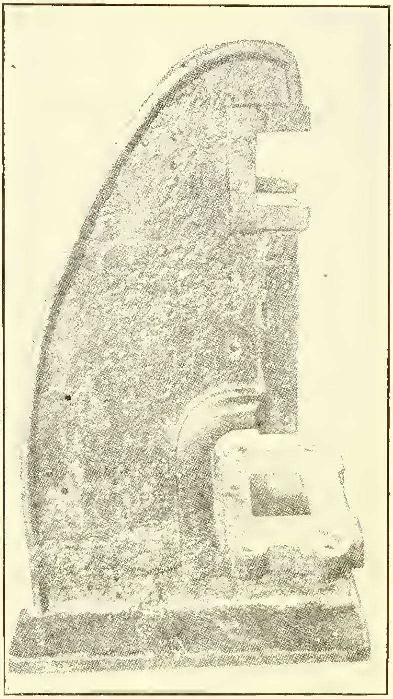


FIG. 146.—The Welded Press Frame.

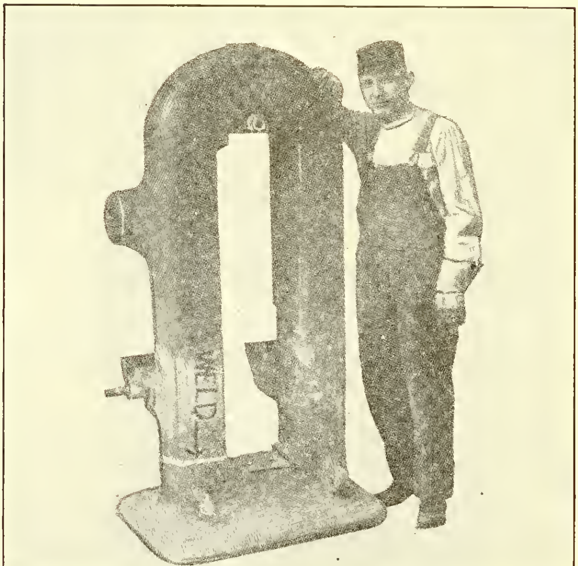


FIG. 147.—Another Welded Press Frame.

size, does not offer any serious welding difficulties, as any possible distortion can be taken care of by subsequent adjustment. The welds made in this particular case were 12 in. in thickness, and the total time taken to get the press back in service was 38 hr.

The saving of defective castings may often prove a very im-

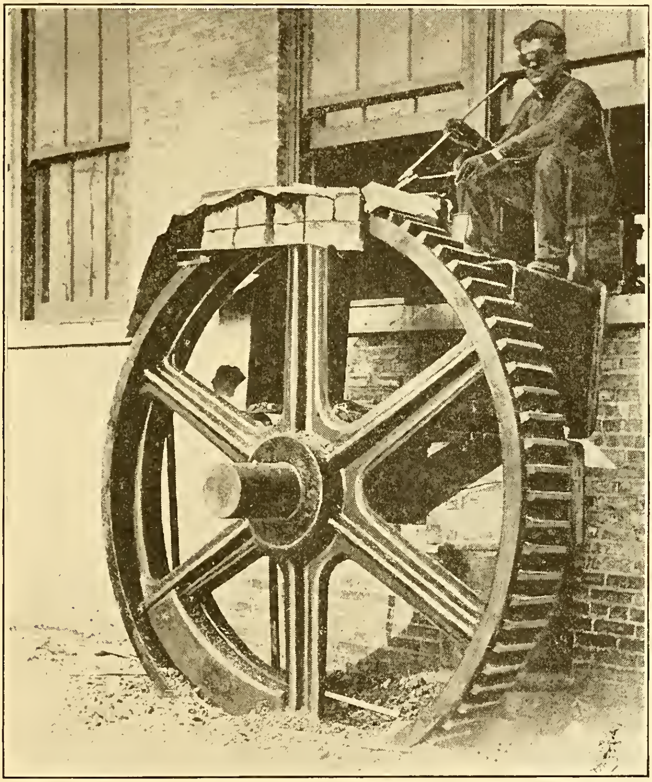


Fig. 148.—Welding Teeth in a Large Gear.

portant item to the shop management. In Fig. 143 is shown a lathe bed, weighing 900 lb., which came from the foundry with sand holes in the pan. These were easily filled up.

Another lathe bed, sand-cracked where the bed leg joined the pan, is shown in Fig. 144. The casting weighed 1750 lb. and was saved from being scrapped by 27 min. of welding work.

A broken frame of a punch press is shown in Fig. 145.

This frame was $4\frac{1}{2}$ ft. high, $2\frac{1}{2}$ ft. wide and from $\frac{3}{4}$ to $1\frac{1}{4}$ in. thick. It weighed 500 lb. The welder's time on the work was $8\frac{1}{2}$ hr.; helper's time, $8\frac{1}{2}$.; oxygen used, 425 cu.ft.; acetylene used, 327 cu.ft.; cast-iron filler, 4 lb.; preheating, 4 hr. with gas at a cost of 60 cents. The total cost to-day can be computed by taking the present cost of labor and supplies and multiplying

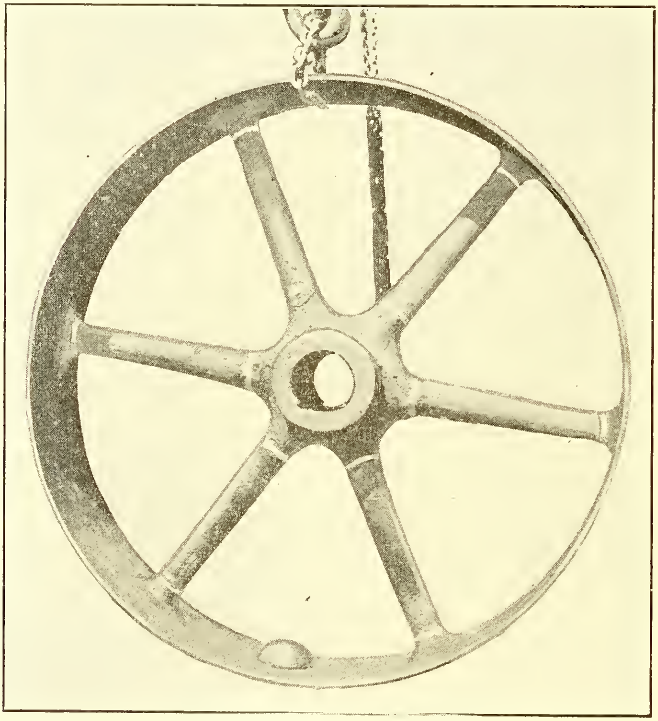


Fig. 149.—A Large Pulley Welded in Twelve Places.

by the figures given. The finished job is shown in Fig. 146. An Oxweld torch was used.

A much simpler, and in fact almost an ideal piece to weld, is shown in Fig. 147. The frame is 12 × 12 in. at the break.

Ten teeth were broken out of the gear shown in Fig. 148. The gear was 8 ft. in diameter and the teeth 10 in. long, 3 in. high and 3 in. thick. It is seldom necessary to preheat in a case of this kind except to save gas, but care should be taken to keep the heat in as much as possible.

A practical man would at once question the advisability of trying to repair a pulley broken as indicated in Fig. 149. This pulley is 7 ft. in diameter and was completely welded in 12 places as indicated, and ready for service in 48 hr. The work was done so well that the rim ran practically true, except for about $\frac{1}{4}$-in. side play. This particular case was a war-emergency job, but sometimes such a repair job is of vital importance at

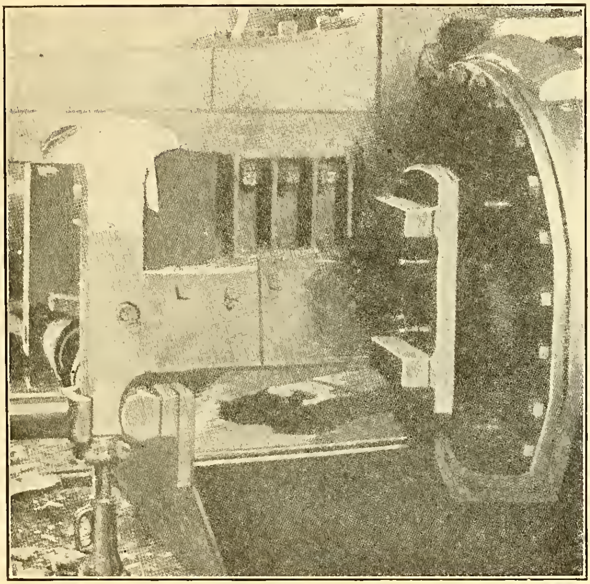


Fig. 150.—A Welded Locomotive Frame.

the present time, for such a pulley can seldom be replaced by a new one without considerable delay.

In many instances broken locomotive frames may be quickly repaired with the gas torch without dismantling, and the engine put back into service in a short time. Such a repair is shown in Fig. 150. This job took altogether less than 24 hr. from the time the engine was run in until it was on the road again.

PREPARATION FOR LOCOMOTIVE FRAME WELDING

Writing in the *Welding Engineer,* G. M. Calmbach, superintendent of welding for The K. C. Southern Railway, gives directions for the preparation of a locomotive frame for welding.

"Tram frame and check with opposite slide, then tram over break locating permanent points by which the expansion will be governed. See Fig. 151 for expansion.

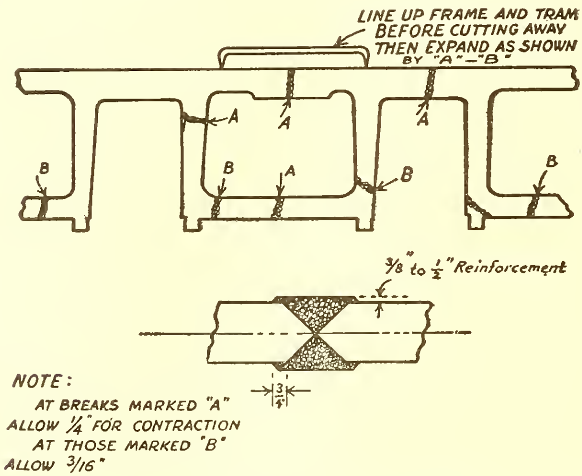


Fig. 151.—Locomotive Frame Welding.

"Frame should be cut out from both sides as shown, then surface to be chipped absolutely clean preparatory to welding.

"Weight of engine should be taken off of frame and jacks placed under legs of jaws on either side of weld.

"Where welds are to be made in any part of jaw binder should be in place if possible.

"As an expedient to start the weld ⅜-in. plate should be tacked to lower side of frame on which a foundation can be made to start the weld, welding plate solid to frame and also welding edges of plate, this plate to extend out on both sides of frame the thickness of reinforce.

"Two operators should be always employed, that is, one on each side of frame. After weld reaches the thickness of 2 in.

it should be hammered, this hammering to continue until weld is finished.

"It is important that at no time during progress of weld that any part of weld be less than a red heat, that is to say, operators should keep finished part of weld red hot at all times and when weld is finished, the entire weld should be brought up to an even heat before jacks are removed."

The gas torch is almost as useful for welding around a shipyard as it is in a railroad shop. Fig. 152 shows a 4-ton forged-steel rudder frame broken as indicated by the arrows.

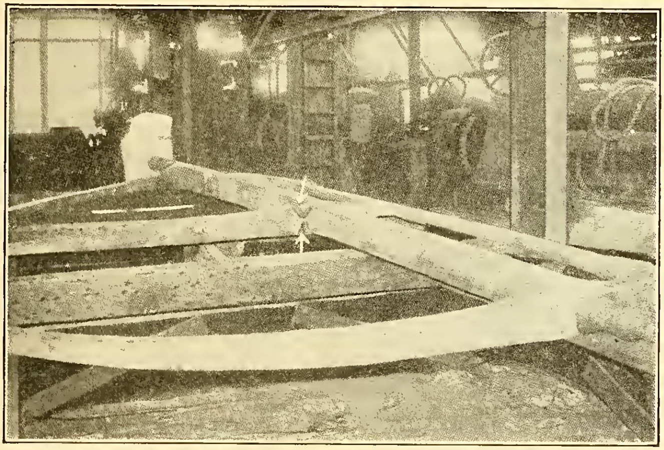


Fig. 152.—Rudder Frame Ready for Welding.

The break has already been beveled out for welding. The cost was about $60 as compared with about $1400 for a new frame, and the time taken was a fraction of what would have been required to obtain a new one.

COOLING DEVICES

On many large jobs, where considerable preheating has to be done, the discomfort of the welder may cause defective welds or even complete failure. Sometimes asbestos screens can be used; at other times it is necessary to shift welders every few minutes. Two suggestions that may be helpful in certain cases are here given. H. Howard suggests the use of an "air screen" as outlined in Fig. 153. A row of small holes is drilled in a pipe of convenient size to attach to the air hose. The other end of the pipe is closed. This contrivance is placed across under the torch and held by a clamp or a weight in such a position that a curtain of swiftly moving air passes between the hot casting and the operator. The device affords protection from the heat and does not interfere with the manipulation of the torch or obstruct the view of the operator.

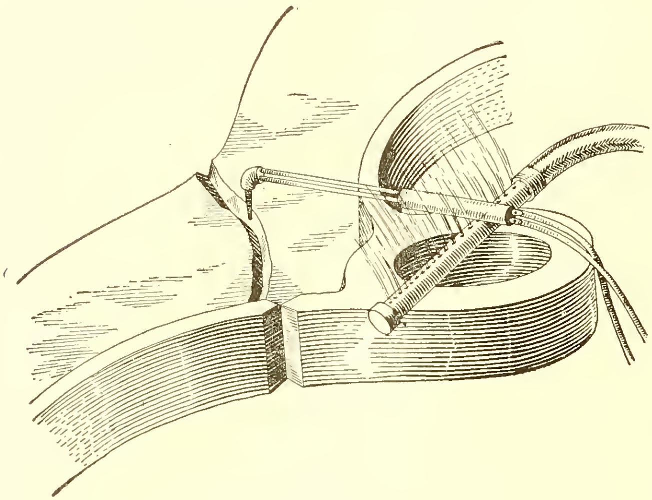


FIG. 153.—Cooler for Use in Welding.

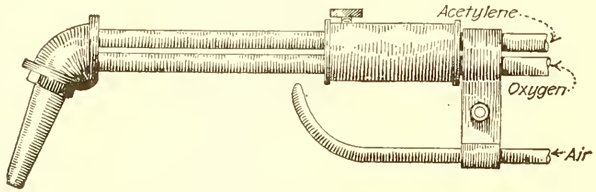


FIG. 154.—Another Cooling Device.

This device, while useful for certain jobs, has disadvantages, as it does not follow the movements of the operator. J. R. Cumming suggests the one shown in Fig. 154. A $\frac{1}{4}$-in. air pipe is fastened to the gas torch by a light iron clip. The air pipe is connected by a light hose to the air supply. By the exercise of a little ingenuity in making this attachment, an operator can keep his hands and face reasonably cool on many jobs that would otherwise make him exceedingly uncomfortable.

The way to prepare seams in boiler and tank welds has already been shown, and only one example will be given. Fig. 155 shows a tank which in use has to stand a pressure of from 200 to 300 lb. It is 4 ft. in diameter and 5 ft. long. The shell is made of $\frac{5}{8}$-in. plate and the dished bottom of $\frac{3}{4}$-in. plate. The longitudinal seam is welded, and the bottom welded to the shell in 6 hr., at less than the cost of riveting, and no caulking is needed.

There have been extensive tests on the strength of gas-torch

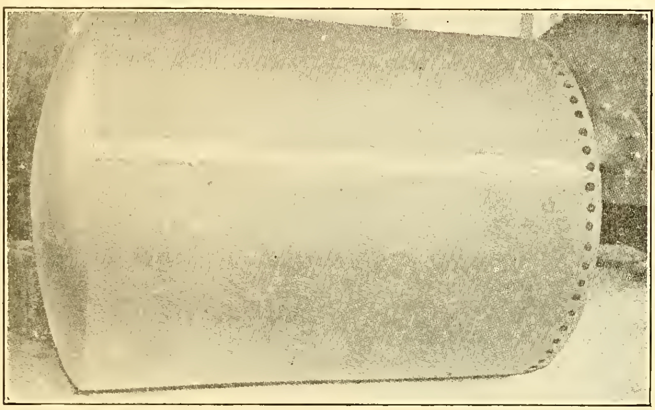


Fig. 155.—A Welded Tank.

welds on boiler plate and the following results are given by the Oxweld Company:

No. of Specimen	Dimensions	Area in Sq.In.	Breaking Load	Stress per Sq.In.	Efficiency of Weld
1	1.522 × 0.393	0.598	25,130	42,000	84%
2	1.554 × 0.380	0.592	23,000	42,800	86.6%

This efficiency is figured on the basis of 50,000 lb. per square inch as the ultimate tensile strength of the material, elongation $^3/_{16}$ of an inch in 2 in. as welded, or about 9.3 per cent.

The average of a number of similar tests taken at random from a considerable list was 79 per cent.

A comparison between the cost of welding and riveting shows that up to certain thicknesses of plate, notably $\frac{3}{8}$ in., welding is cheaper per lineal foot than riveting. On heavier material than this, however, the cost is usually about the same as good riveting practice.

The speed and cost per foot of welding with an Oxweld torch for different thicknesses of plate are:

Thickness of Metal, In.	Lin.Ft. per Hour Welded	Cost per Foot
1/8	20	$0.04
3/16	15	.06
1/4	10	.09
3/8	6.5	.23
1/2	6.0	.27
5/8	4.5	.35
3/4	3.0	.60
1	2.0	1.20

This table is compiled from results obtained from actual shop practice. The price of oxygen is figured at 2 cents per cubic foot, acetylene at 1 cent and labor at 30 cents per hour. Other gas and labor costs can readily be substituted to meet any local conditions.

RAIL BONDING

Electric rail bonding, such as shown in Fig. 156, is very easily done with the gas torch. Fig. 157 shows a welder at

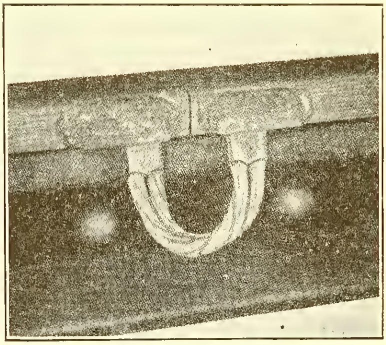


FIG. 156.—Electric Rails and Welded on Bond.

work on a job of this kind. The apparatus used is mounted on a special truck so as to be easily moved along the rails from one joint to the next requiring bonding.

The filling up of blowholes, cold shuts and cracks in castings of various kinds is well known to most foundry workers, but the building up of worn or over-machined parts is not so familiar to the general run of mechanics.

A good example of the reclaiming of an expensive casting worn in service is shown in Fig. 158. This is the casing of a circulating pump. A strip of metal about 3 in. wide and $\frac{3}{4}$ in. thick had to be built up around the entire inside edge of the casting. The work was done by two operators working as

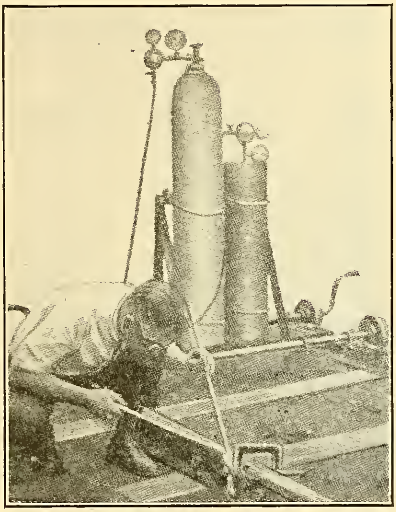


FIG. 157.—Bond Welding Outfit in Use.

shown. The added metal was then ground smooth enough for the purpose and the casing put back in service.

Building up worn pods on steel-mill rolls is shown in Fig. 159. A rough brick furnace is built around the end to be welded and charcoal used to heat up the work to save gas. The welding in this case was done with thermalene, but any good gas outfit may be used with good results.

The large chain belt links, Fig. 160, were cut undersize on the corners and were reclaimed by building up as shown.

Aluminum automobile transmission or other castings often come through slightly defective. To recast them would mean a duplication of costs in cores, molds, handling and turning,

FIG. 158.—Building Up Worn Parts of Large Pump.

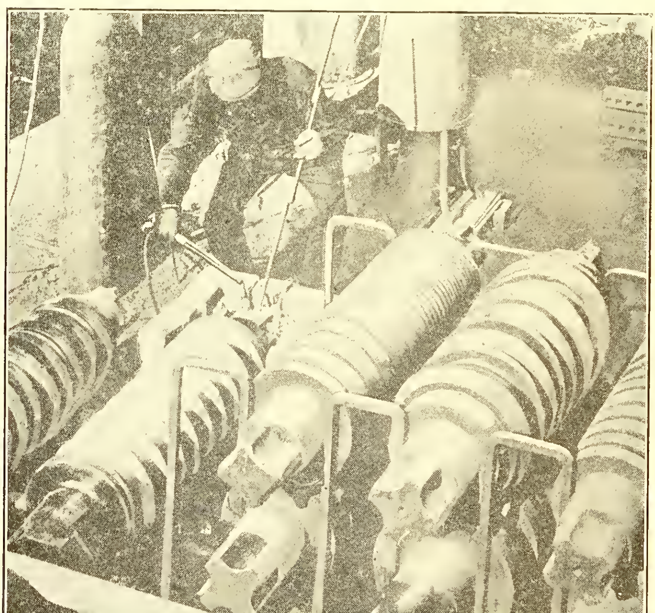


FIG. 159.—Welding Pods on Steel-Mill Rolls.

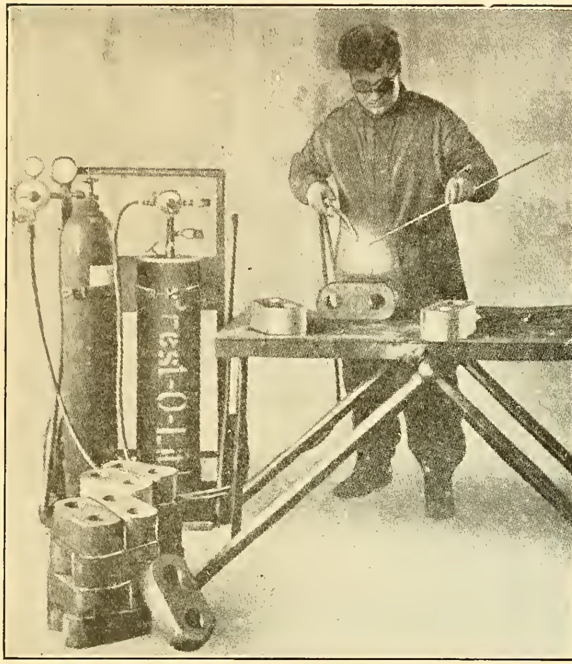


FIG. 160.—Building Up Over-Machined Chain Links.

FIG. 161.—Filling Blowholes in an Aluminum Gear Case.

which would mean a considerable loss. They are welded—the holes filled with similar metal from a "filler-rod" as shown in Fig. 161—at a cost of but a few cents each and they pass inspection as being as good as perfect castings.

Through error four cast-brass U-plates for rudder frames, Fig. 162, weighing 1000 lb. each, were made 6 in. too long.

To repour these plates would have held up some important

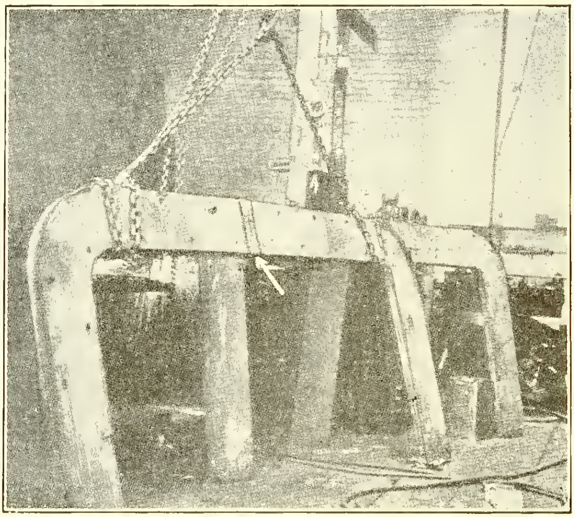


Fig. 162.—Brass Rudder Frame Salvaged by Welding.

work and the expense, including change of pattern, would have been very high. The mistake was quickly and economically corrected by cutting 6 in. out of each as shown by the illustration and welding the frames together again.

A REMARKABLE CYLINDER WELDING JOB

Writing in the *American Machinist*, Jan. 8, 1920, L. M. Malcher, superintendent of the Chicago shop of the Oxweld Acetylene Co., says: One of the 5000-hp. Allis-Chalmers twin tandem compound reversing steel rolling mill engines at the Farrell works of the Carnegie Steel Co., Farrell, Penn., that had been doing its full share in helping to win the war broke down two weeks after the signing of the armistice. In the accident, besides other parts, the left-hand low-pressure steam cylinder, Fig. 163, 70 in. inside diameter, was badly fractured, as a result of the breaking of a connecting-rod at the moment of reversal.

It would have taken at least three to three and one-half months to obtain a new cylinder, in case the broken one could not be repaired in a shorter time; besides throwing 360 men out of employment. The broken cylinder was of such size and the damage done was of such character that a decision whether

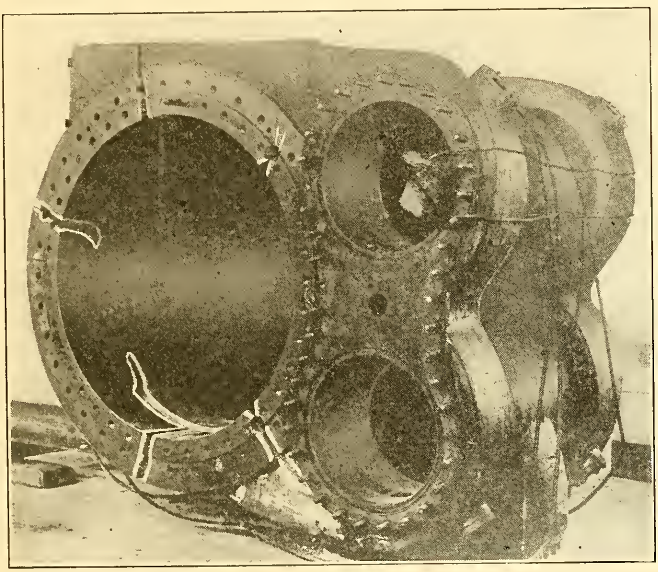


FIG. 163.—Wrecked Low-Pressure Cylinder.

The seven cracks ranged from 1 to 8 ft. in length and $2\frac{1}{4}$ to $3\frac{3}{8}$ in. in depth and are shown V-grooved by chipping preparatory to welding.

the cylinder was to be renewed or repaired involved a risk on the part of the management.

Although it was decided that consideration of expense between the cost of purchasing a new cylinder and the repairing of the old one were of secondary importance, the cost of repairing was estimated to be about one-third that of a new cylinder.

Decide to Make Repair.—The officials of the company after having made a careful investigation quickly decided in favor of oxy-acetylene welding. They called upon the job welding shop of the Oxweld Acetylene Co., Chicago, Ill., to meet the emergency. Three expert welders, accompanied by all necessary equipment, went immediately to Farrell and completed the job under the direction of the writer.

The fractures of the cylinders were what are commonly known as "end breaks"; that is, the cracks are on the extreme

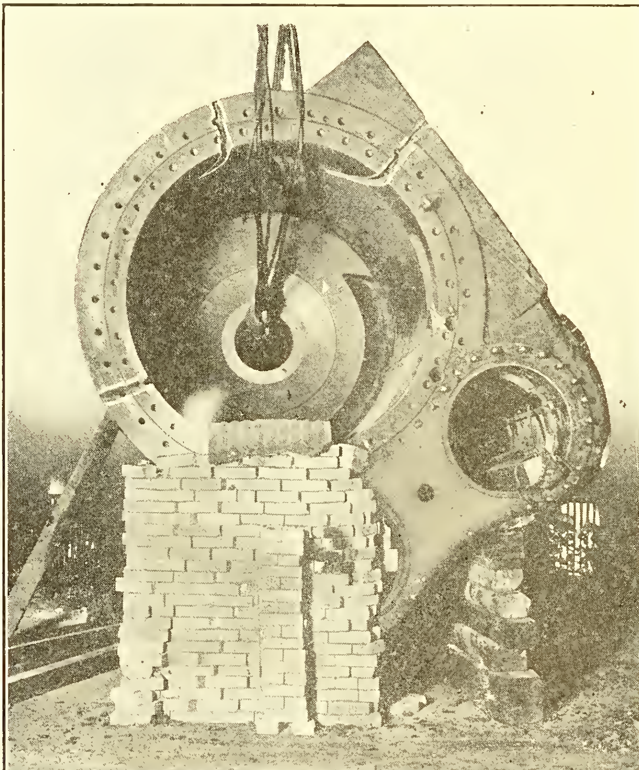


Fig. 164.—Preheating Crack in Low-Pressure Cylinder by Means of Charcoal Fire.

outside end of the casting. As a rule it is only necessary to preheat the casting locally (Fig. 164), and while the heat will radiate into the casting to some extent, the intensity is not enough to harm any portion by warping or shrinkage. The total time consumed in repairing the low-pressure cylinder, including chipping, preheating and welding, was 72 hours.

While dismantling the engine a fracture was discovered in the right-hand, 42-in. diameter, high pressure cylinder. This fracture also was repaired in about 18 hours. It took just seven days from the time the order was placed to complete the entire job.

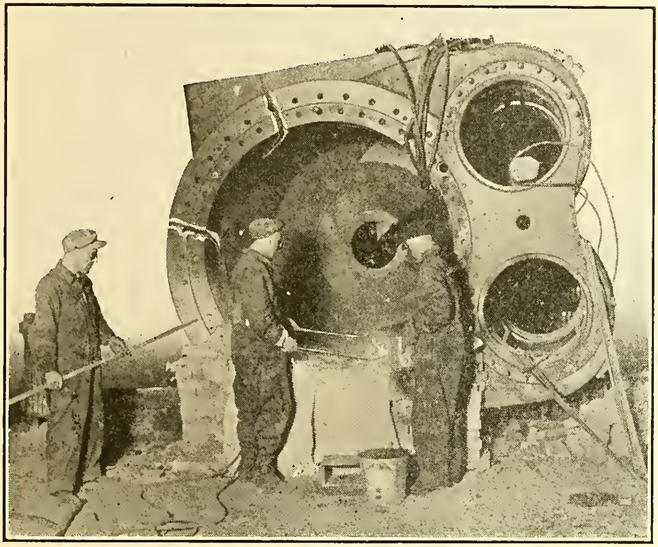


FIG. 165.—Welding the Low-Pressure Cylinder.
Asbestos paper was used to protect workers and retain heat from preheating fire. Note the extra long torches and rods required for the long cracks.

The data covering this work are given in detail in the accompanying table.

	Low-Pressure Steam Cylinder	High-Pressure Steam Cylinder
Cylinder bore	5 ft. 10 in.	3 ft. 6 in.
Stroke	4 ft. 6 in.	4 ft. 6 in.
Weight of cylinder	13 tons.	5 tons
Thickness of iron casting	$2\frac{3}{4}$ to $3\frac{3}{8}$ in.	$3\frac{1}{2}$ to 6 in.
Total length of weld	22 ft. 2 in.	4 ft. 6 in.
Preparing and preheating casting	27 hr.	$9\frac{1}{2}$ hr.
Welding casting	45 hr.	$8\frac{1}{2}$ hr.
Oxygen consumed	2850 cu.ft.	650 cu.ft.
Acetylene consumed	2845 cu.ft.	650 cu.ft.
Cast iron welding rods	390 lb.	110 lb.
Flux	25 lb.	10 lb.
Number of welders	3	3
Period of welding shifts	10 and 30 min.	10 and 30 min.

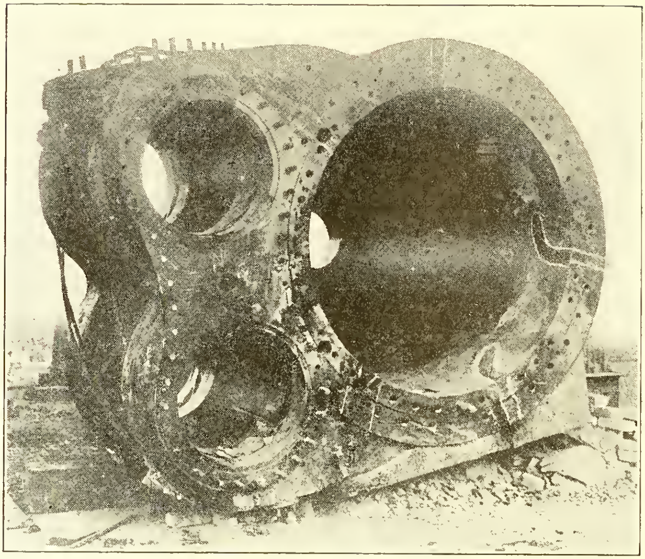


FIG. 166.—Welding of Low-Pressure Cylinder Completed.

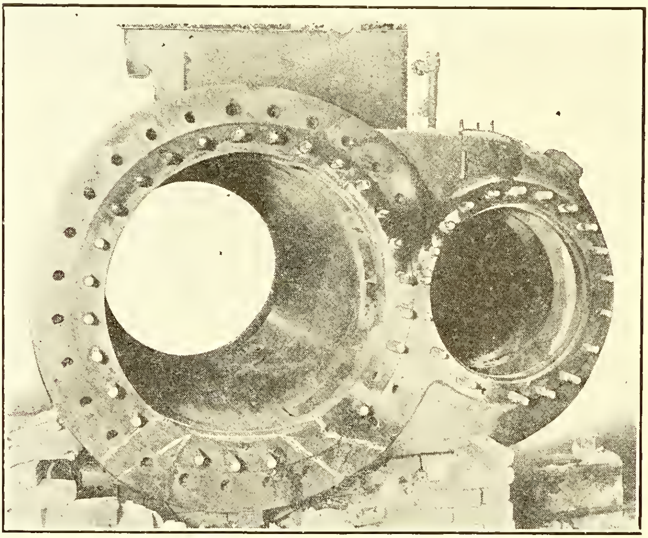


FIG. 167.—Flange Welded on the 5-Ton High-Pressure Cylinder.
Weld $4\frac{1}{2}$ ft. long, $3\frac{1}{2}$ to 6 in. deep.

While welding inside of the cylinder castings, as shown in Fig. 165, the men relieved one another every 10 min. because of the extreme heat deflected back on them during the welding operation. On the outside welding, however, the heat was not so intense and the men relieved one another every 30 min.

After the engine cylinders were machined, it was almost impossible to determine where the cracks had occurred, as can be seen from Figs. 166 and 167.

The total cost of the complete repair represented but a small fraction of the replacement cost, but even this saving is insignificant when compared with the disorganization which would have resulted from the laying off of a large body of trained workmen and with the enormous loss that would have been entailed in a stoppage of production.

WELDING HIGH SPEED TOOL TIPS TO LOW CARBON SHANKS

The welding of tips of high speed steel to low carbon shanks is perfectly feasible and several methods of performing this work are in successful use. As a means of lowering costs of production the process commends itself to manufacturers, engineers and plant managers, says the *Welding Engineer*.

The principal reasons for the failures of the welder who attempts this class of work is because of his ignorance of the class of steel he is attempting to weld and because of a lack of practice. Therefore, it is plain that to acquire skill in the welding of high speed tips to low carbon steel the operator must not be discouraged by a few failures, but must master the problem by study and practice.

So far as the low carbon steel used as shanks is concerned, this steel may be roughly divided into three general classes: Cold drawn, open hearth and Bessemer. The high carbon steels are more numerous and many metals enter into their composition. No doubt the bulk of the welder's failures would be eliminated if he had a perfect understanding of the varied and intricate analysis of many of the high carbon steels of the day. He often fails to appreciate that, controlling a heat of 6300 deg. F. he plays it unnecessarily long on a steel which melts at from 1800 deg. to 2500 deg. F., which results in burning the metal. In the mills where such steel is made, should a furnace be allowed to reach such a temperature, an entire heat would be destroyed.

The first step in welding high speed tips to low carbon shanks is the preparation of the shank, which is beveled as shown in Fig. 168. The tip of high speed steel is not to be beveled. The shank and tip should then be sand blasted, after which the sand dust should be wiped off the surfaces to be welded. It is good practice to preheat both the shanks and the tip to a cherry red (about 1375 deg. F.). Then build up $\frac{1}{8}$ in. of metal on the surface of the shank that is to be welded, and also on the surface of the tip which is to be welded, using a $^3/_{16}$ or $\frac{1}{4}$ in. nickel steel welding rod and a flux such as is used for cast iron.

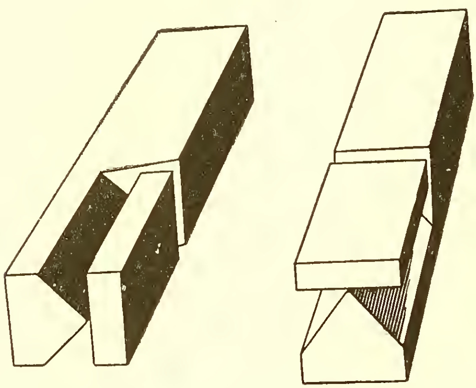


Fig. 168.—One Method of Preparing the Shank and Tip.

Then place the tip in the position it is to occupy and tack it and weld one side with a nickel steel rod. A flux is not necessary. Turn the tool over and weld the other side. Both sides should be welded from the end, progressing toward the heavy portion of the shank.

The reason for this is as follows: The low carbon steel shank will absorb heat more rapidly than the tip. As the flame is progressing towards the shank the tip is therefore subjected to as little heat as possible, and the shank will absorb the most of it.

Now set the tool up and weld the sides and top, where the high speed steel joins the low carbon shank. In order to reduce as much as possible the interval between the beginning and the ending of the welding operations a sufficiently large tip should be used and care should be taken that the flame is not played on one spot too long, or the metal will be burned.

It will be noted that a nickel steel welding rod is recommended, although in justice to some very capable welders it may be said that in certain shops both Norway or Swedish iron rods and Vanadium steel is being used. The author believes, however, that the results attained justify the statement that nickel steel rods are preferable.

Many welders overlook the fact that the physical properties of high speed steel and ordinary tool steel are so different that strains are set up by welding. Therefore it is essential that the welded tools be heat treated before cooling from a welding operation. When possible a furnace should be used for this purpose. If the life of the tool is of but short duration, it is sufficient to bury it in lime or asbestos as soon as the welding operation is completed. Another good method is to place the tool on end and in a tank which contains any good mineral oil. This tempering or hardening process should take place directly after the welding operation and before the tool cools.

As was pointed out at the beginning of this article, in the welding of high speed tips to low carbon shanks, much depends on the operator. In ordinary tool-room work when a difficult or intricate tool or jig has to be made, the foreman selects one of his best men to do the work. In the case of failure, the human element is blamed. With the oxy-acetylene process, however, the blame is too frequently placed on the process or the apparatus. Too often the verdict is, "No good for that kind of work." This snap judgment is usually due to a lack of knowledge on the part of both the welders and their foremen. In handling work of such a special character as welding tools it should be understood that the welder should, if he is not already experienced in that work, be given an opportunity to study and practice and his first failures should neither condemn him or the process. The results to be derived from patience will justify the expense of the welder's training.

G. A. Hastings, in the *American Machinist,* says: "Our high-speed steel scraps consisted of all sorts of short ends. Owing to the high price of steel we decided to try oxy-acetylene welding to utilize the ends on a mild-steel shank. We prepared for the weld, as shown in Fig. 169, and have turned out lathe, shaper and planer tools that give entire satisfaction.

The high-speed points were cut with a hot set and ground to the proper shape, the welding edges being beveled toward the center at about 45 deg. The shank was made in the same way and the weld made with an ordinary steel-welding rod. We figured that making the weld at an angle of 45 deg. from

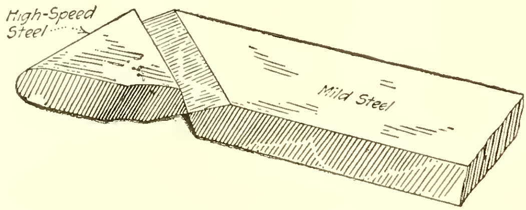


Fig 169—Another Method of Preparing the Shank and Tip.

the base would give the welded point a better support from the end of the shank and reduce the stresses at the weld.

The first tool made cost about 35c. excluding the somewhat doubtful value of the high-speed scrap used for the point. Later tools, of course, cost less.

Regarding Presto-O-Lite Co. practice, A. F. Brennan says: "The weld is made in the following manner: Both the machine

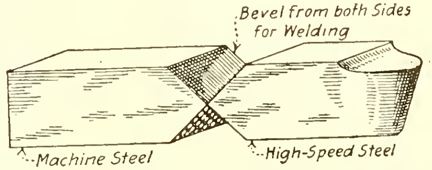


Fig. 170.—Prest-O-Lite Tool Welding Practice.

steel and the high-speed steel are beveled from two sides by grinding, as shown in Fig. 170. It is important that this bevel extend clear to the center of the piece and that the angle be a generous one—at least 90 deg. It has been found that a nickel-steel welding rod made of a low-carbon steel containing about 3 per cent nickel gives the best results, and no flux is used.

"The weld should be executed just as though both pieces were of machine steel, except that greater care should be taken to insure the penetration clear to the center of the parts being welded; and it will probably be found necessary to "puddle" or "work" the molten metal with the filling rod, as some grades of high-speed steel do not flow readily under the torch. Wherever possible, the weld should be built up or reinforced, although in some cases this is impossible, as when the welded portion is to be used inside the tool holder. In such cases the

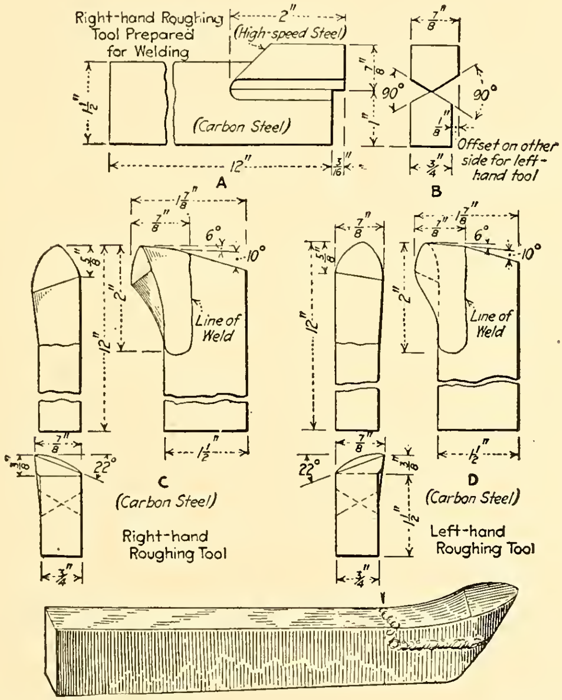


FIG. 171.—Details of Tools with Oxy-acetylene-welded Points.

weld has to be ground off level. After the weld is completed, the tool can be ground and tempered in the usual manner.

"A tool 1 × 1 in. can be welded, if properly beveled, in about 10 min. with a No. 6 tip. The oxygen consumption for this operation is about 5 cu.ft., and the acetylene consumption is approximately the same. On this basis the labor costs are 5c., acetylene and oxygen 10c. each, and filling material 5c.

"I have never welded on any points of high-speed steel less than about an inch and a half long; but if the material is properly handled, I believe that this length could be reduced.

"When it is remembered that the price of high-speed steel has risen greatly, the practice is worth considering.

"Further, there are oftentimes short ends of high-speed steel that are not long enough for use. They are usually sold for scrap, but may be used to advantage by this method."

The practice of the Root & Vandervoort Engineering Co., East Moline, Ill., is as follows: The mild-steel shank and high-speed steel point or bit are shaped as shown at *A* and *B*, Fig. 171. The details give the proportions of one kind of round-nose turning tool for roughing cuts, and for both right-hand and left-hand setting. The shanks and points may be forged or machined to the shapes given, but in the case of forgings the angular surfaces must be ground to free them from scale.

When welding, the tool is laid on its side and the parts blocked up so that they are in proper relation to each other. They are then welded, using an oxy-acetylene welding outfit, with a torch having a tip, giving a flame about $\frac{5}{8}$ in. long. Round Norway iron $^3/_{16}$ in. in diameter is used for filling, and care is taken to prevent the flame from directly touching the high-speed steel point. The operator keeps the welding rod between the flame and the piece of high-speed steel. The angular grooves on the sides of the tool, as shown at *B*, are filled up a little more than flush and most careful attention is given to see that a first-class weld is made.

After the tool is welded, no hammering of any kind is done on it, and all shaping is done by grinding. After rough grinding, the tool is hardened in the usual manner, and then after finish grinding, it is ready for use.

The finished shape and dimensions of a right-hand roughing tool made by this method are shown at *C*, and a similar left-hand tool at *D*.

In another article, Herbert V. Ludwick writes: Owing to the high cost of high-speed steel, the practice of welding high-speed tips to machine-steel shanks is of interest to manufacturers. Welding a high-speed steel tip to a machine-steel body for cutting off tools for automatic machinery has been more or less a difficult problem, owing to the shock the weld has to stand from the constant chatter of the stock against the tool.

Take two pieces of high-speed steel *A*, Fig. 172, $\frac{3}{8}$ in. square by 2 in. long, and grind a $\frac{1}{4}$-in. radius on the end of each. A rough machine-steel body is milled at both ends as illustrated at *B*. The parts are assembled and put in the jig *C*, which is

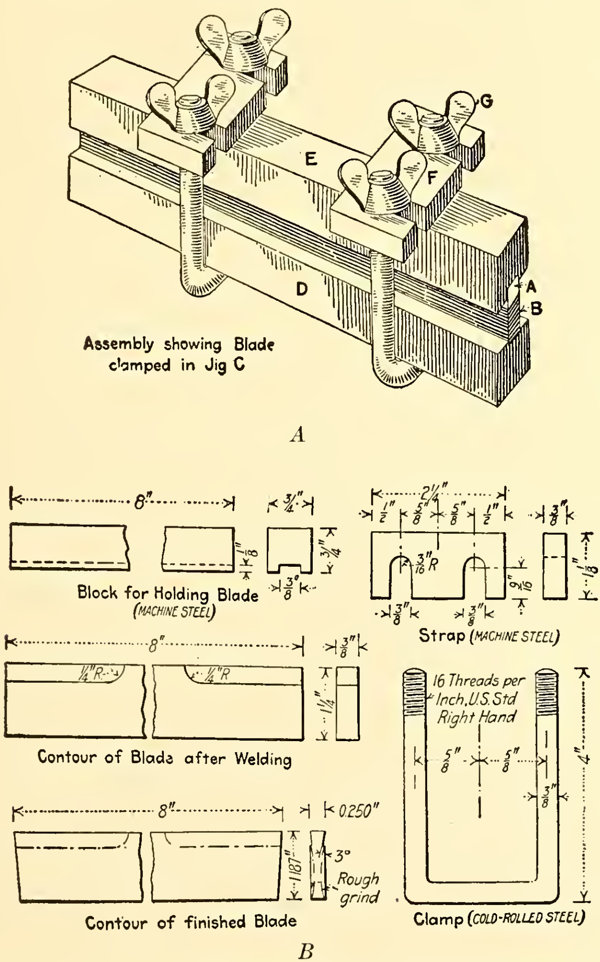


FIG. 172.—Jig for Welding High-speed Steel Tip to Machine-steel Body.

made from two pieces of $\frac{3}{4} \times \frac{3}{4}$-in. machine steel *D* and *E*. They are fastened with two clamps *F*, made of flat steel held by $\frac{1}{2}$- or $\frac{3}{8}$-in. U-bolts *G*. Wing nuts should be used if at all possible, as they are easily and quickly adjusted.

The reason for using the jig is that when the flame of the torch is directed on the places to be welded it heats the tips and the body of the blade very quickly and causes the steel in the blade to expand before the jig has time to get very hot. These two bodies, when heated until they run at the weld, are forced together by their expansion, resulting in a better weld.

The work should be removed from the jig quickly and placed in powdered lime or bar sand, to prevent chilling and the formation of hard brittle spots in the weld, which are difficult to machine even after the regular annealing process.

CHAPTER XIII

WELDING JIGS AND FIXTURES

Where a welding shop does a general line of work which includes everything that comes, there should be an ample assortment of drilled straps, angle irons, bolts, V-blocks, clamps,

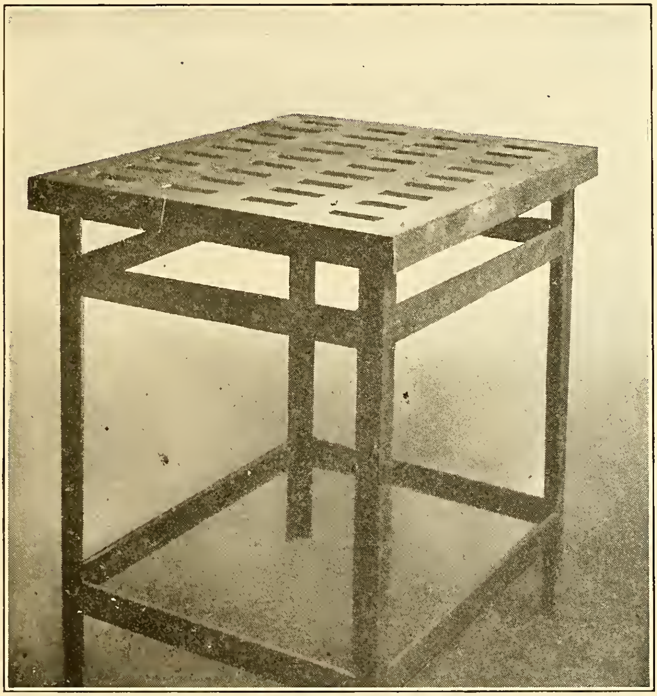


FIG. 173.—Table for Holding Welding Work.

plates and the like. Good supplies of fireclay and plaster of paris are also very desirable for supporting or holding irregular work that is apt to collapse or get out of line. Many times, a table such as shown in Fig. 173 will answer for certain jobs.

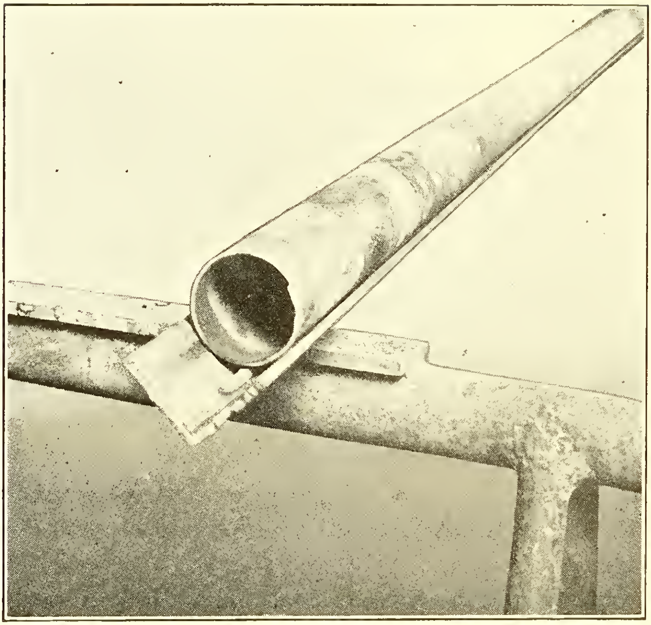


FIG. 174.—Holding Pipe for Welding.

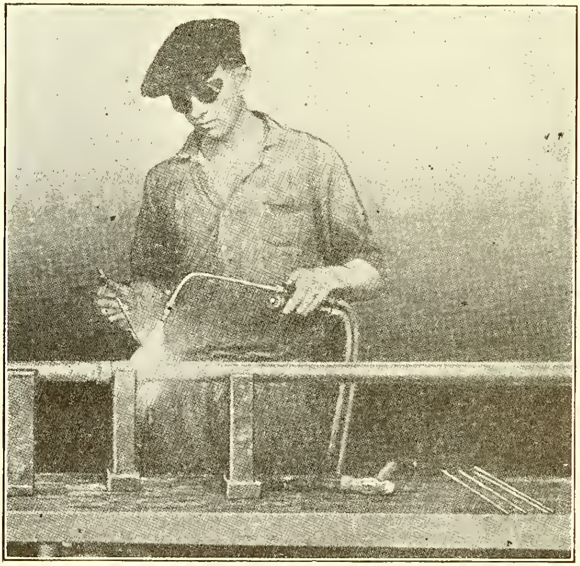


FIG. 175.—V-Blocks for Holding Shafts.

The top of this table is made of a "grated" slab of cast iron supported on a welded angle- and strap-iron frame. The slots provide means for the insertion of clamping bolts. A table similar to this can easily be made in any welding shop.

Pipe welding is a very common and re-occurring job in most shops. Some rig up V-blocks, rollers or other devices, but the method shown in Fig. 174 is very good. It is simply a piece of angle iron placed on iron horses as illustrated. The ends of the pipe to be welded are cut square and the outside ground back for about two or three inches to remove rusty scale and dirt. On long pieces of pipe the grinding may be done with a portable electric grinding machine while the end of the pipe sticks out a foot or so from the end of the channel iron. The pipe in this case remains still and the grinding machine is moved around it as the operator stands in front of the pipe end.

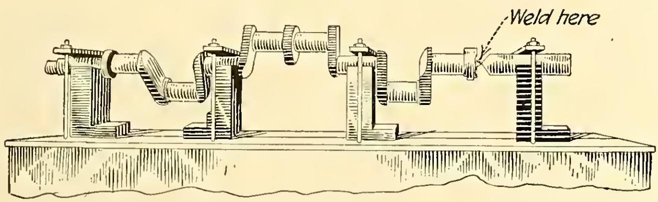


Fig. 176.—Jig for Holding Crankshafts.

The short or easily handled pieces of pipe may be ground on a stationary grinding machine.

The best part about using an angle iron is that the pieces of pipe to be welded are held in line while being tacked together. On ordinary sizes the welder will have no difficulty in turning the pipe as he welds. On heavy pipe some form of rollers will be found very convenient.

A very simple way to weld straight shafts is shown in Fig. 175. Here the shaft simply rests on high V-blocks which keep it in line but do not interfere with expansion or contraction.

A jig for holding a motor crankshaft broken in the shaft is shown in Fig. 176. The main part of the crankshaft is clamped to three V-blocks. The bases of these V-blocks are grooved to fit over a tongue in the baseplate, so that they may be slid along in order to adjust them to various sizes of crankshafts, and yet keep them in line. The V-block holding the

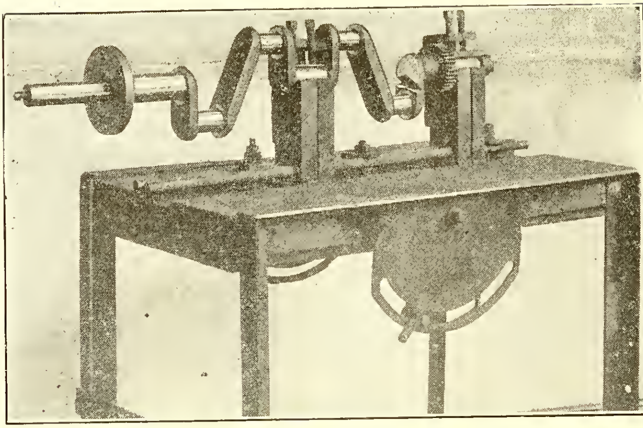


FIG. 177.—An Adjustable Crankshaft Jig.

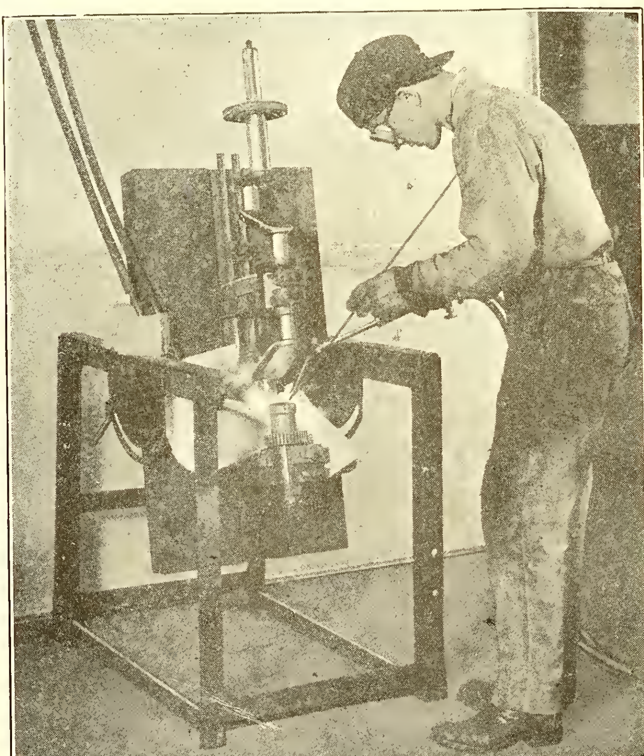


FIG. 178.—Welding a Broken Web in the Jig.

short piece to be welded on is made in the same way, but the piece should *not* be clamped in solidly but should be so held that it can move lengthwise. This may be done by clamping loosely or else having the V-block free to move along the tongue The rigid clamping of all parts would cause distortion and springing of the crankshaft.

The device shown in Fig. 177 is in use in the Oxweld shop.

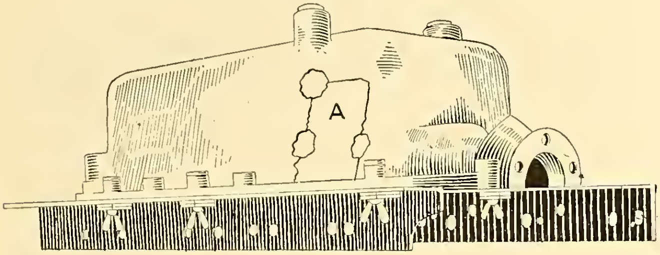


FIG. 179.—Aluminum Crankcase Stiffened by Angle Iron.

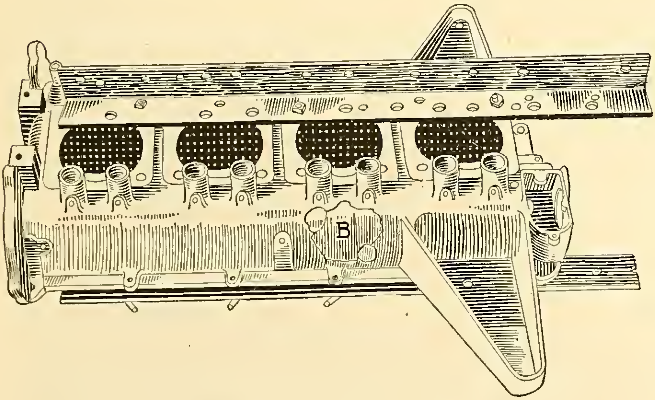


FIG. 180.—Angle Iron Applied to Another Job.

Four V-blocks are made to slide on bars, as illustrated, and may be clamped wherever desired. Each V-block carries its own clamping screw for holding the work. For ordinary shaft welding the table may be used in a horizontal position, as shown, but for welding breaks in webs the table may be tilted as shown in Fig. 178. This illustration also shows the use of a coal-gas and air torch to heat the work while the welder is using the welding torch.

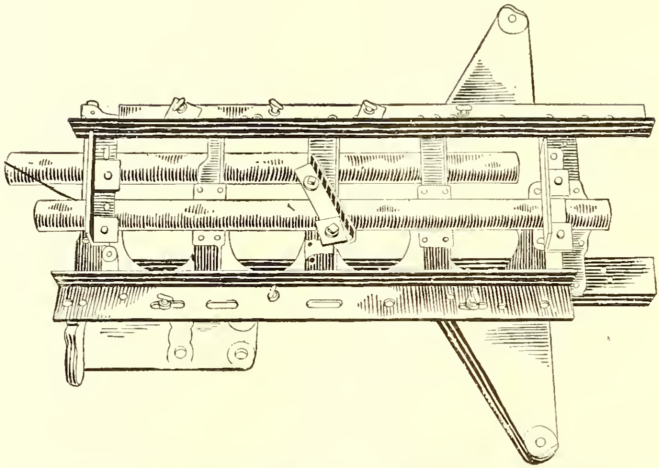


Fig. 181.—Crankcase with Angle Iron and Bearing Mandrels in Place.

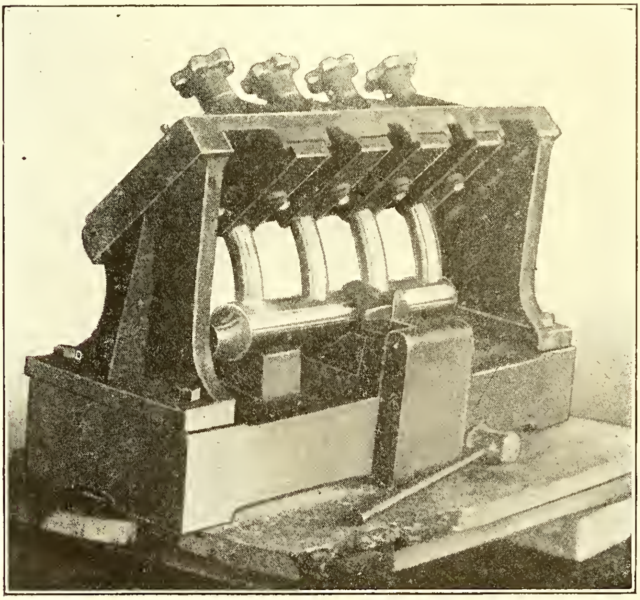


Fig. 182.—Motorcycle Manifold Welding Jig.

Crank cases or other automobile parts may be held in order to prevent distortion as much as possible, as shown in Fig. 179. In this case angle irons and short bolts with wingnuts are all that are needed. The patch to be welded in is shown tacked in place at *A*. Another application is shown in Fig. 180. The patch *B* has been tacked in two places ready for welding.

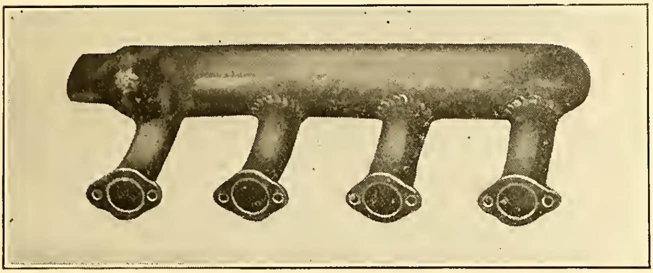


Fig. 183.—A Welded Motorcycle Manifold.

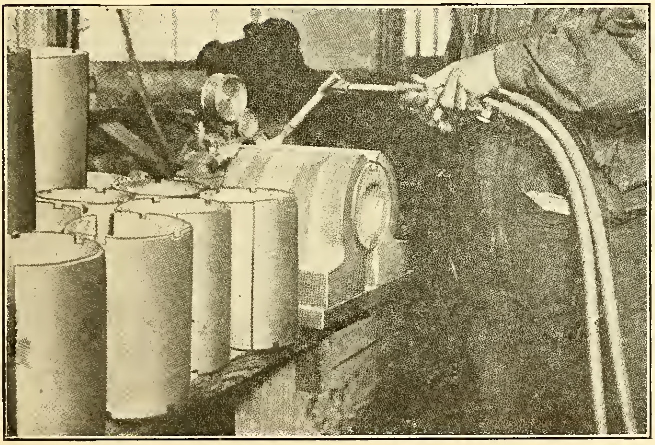


Fig. 184.—A Sheet-Metal Roller Welding Jig.

In Fig. 181 both angle irons and mandrels are used in the bearings. These mandrels may be solid or of pipe to fit the bearings. Sometimes, where it is necessary to keep the bearings cool, a pipe with elbows screwed on each end may be clamped in. With the ends of the elbows up, the pipe may be filled with water.

The Henderson Motorcycle Co. uses the jig shown in Fig.

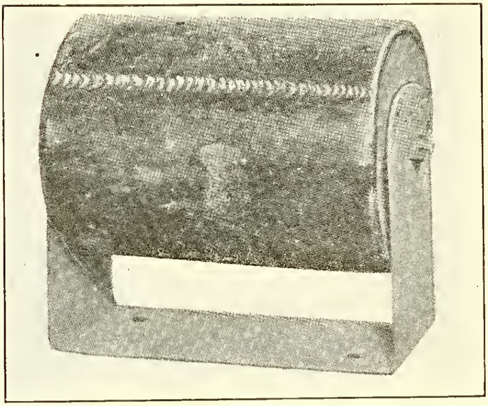


FIG. 185.—A Welded Conveyor Roller.

FIG. 186.—Large Sheet-Metal Cylinder Welding Jig.

182 to hold the parts of their exhaust manifolds while welding. The construction and operations are obvious. A welded manifold is shown in Fig. 183.

Holding Sheet-Metal Cylinders.—A very simple welding jig is shown in Fig. 184. This consists of four castings: the

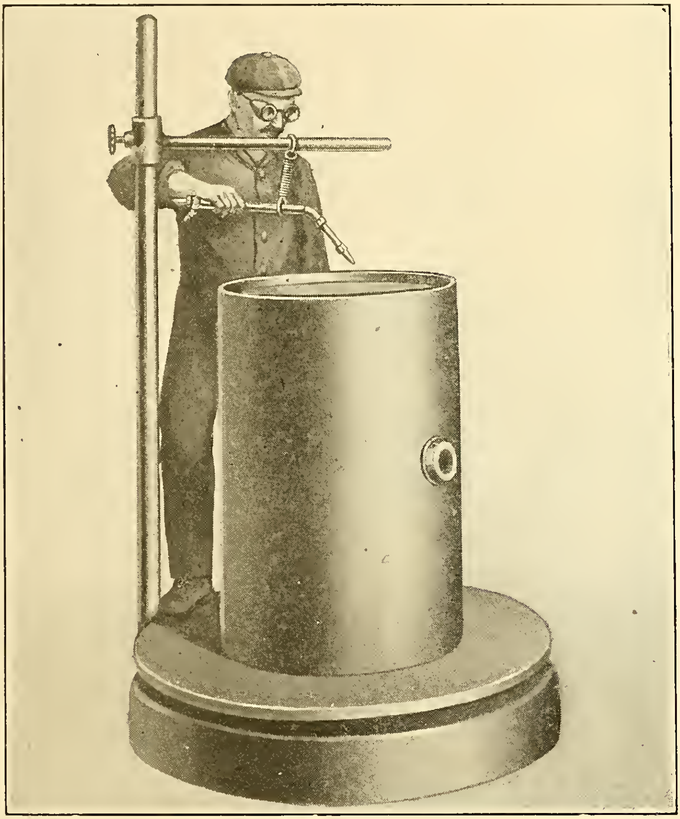


Fig. 187.—Apparatus for Welding Ends in Cylinder or Tanks.

base, two side pieces and the hollow mandrel. The cylinders welded are 6 in. in diameter and $8\frac{1}{2}$ in. long, made of $\frac{1}{8}$-in. plate. They are used to make the conveyor roller shown in Fig. 185. The seam is welded in three minutes.

Another cylinder welding jig is shown in Fig. 186. This is in use in the Thermalene shop. The edges of the cylinder

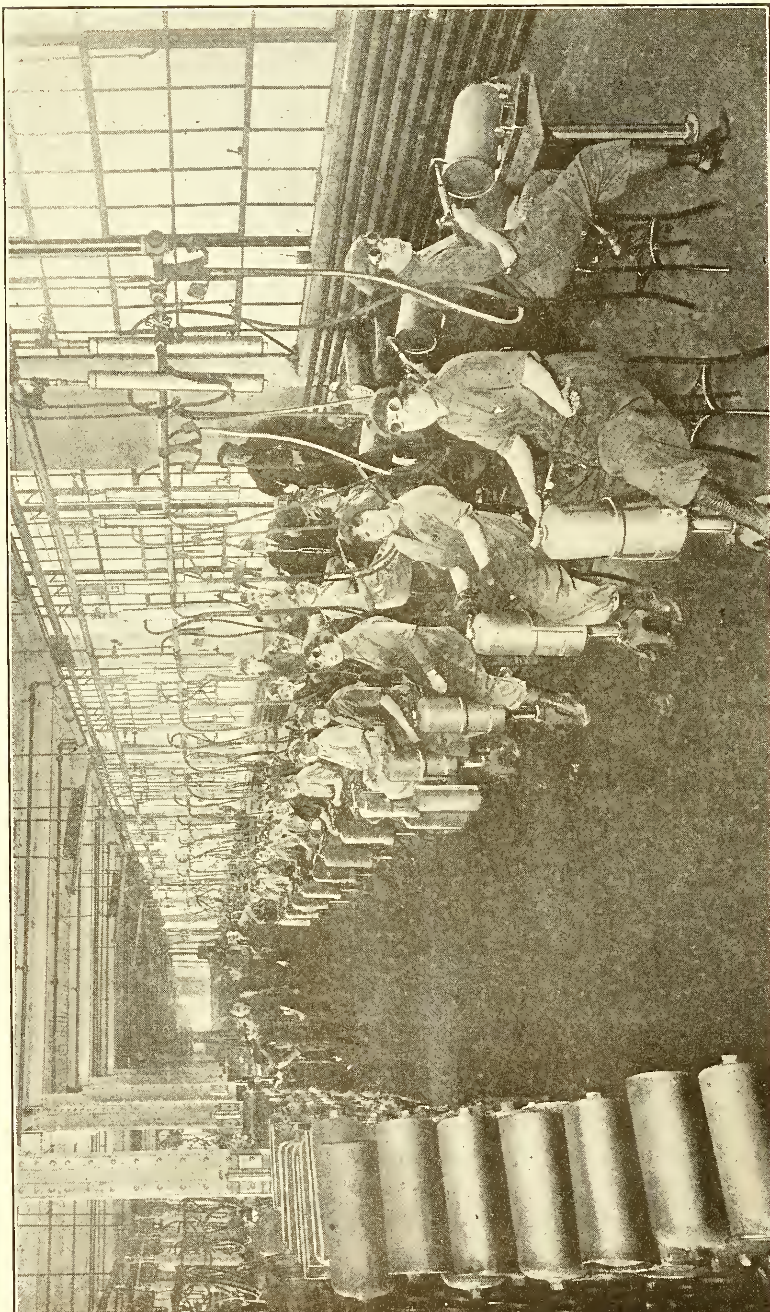


Fig. 188.—Welding Poison-Gas Containers.

to be welded are held up to the V-channel from underneath by a bar locked in place by bolts and large wingnuts.

The speed for welding sheet metal will of course vary widely, but the following approximate results on sheet iron and steel are a fair average:

Thickness of metal	Feet per hour
20 gage	40
18 "	35
16 "	30
14 "	24
12 "	22
10 "	20
8 "	18

The welding of steel barrels of about 30 to 35 gal. capacity, used for oil or gasoline, can be done by an operator of average skill at the rate of 16 to 18 per day. These barrels are made of 12-, 14-, or 18-gage sheet steel, and require one seam weld, two complete end welds, two bungs welded in and a reinforcing ring welded on each end.

In welding the ends on cylinders or drums, the device shown in Fig. 187 is sometimes used. The work rests on a turn table which is rotated by the welder's foot. A supporting arm and a suspension spring assist the welder in holding the gas torch.

The method of welding gas containers for war use with Oxweld apparatus is shown in Fig. 188. As shown at the right, the container bottoms are welded in while resting on rollers set on an inclined base in such a way as to present the work at the right angle.

Fig. 189 gives a better view of the bung welding apparatus, and also shows the excellent method of suspending the torches when not in use.

LIBERTY MOTOR WORK

In describing work on the Liberty Motor in the *American Machinist,* May 29, 1919, H. A. Carhart, mechanical engineer of the Lincoln Motor Co., Detroit, first outlines some of the electrical welding and then says: "The water jacket is fitted to the cylinder, and the latter when assembled, is placed in a clamping fixture, Fig. 190. This fixture consists of a frame

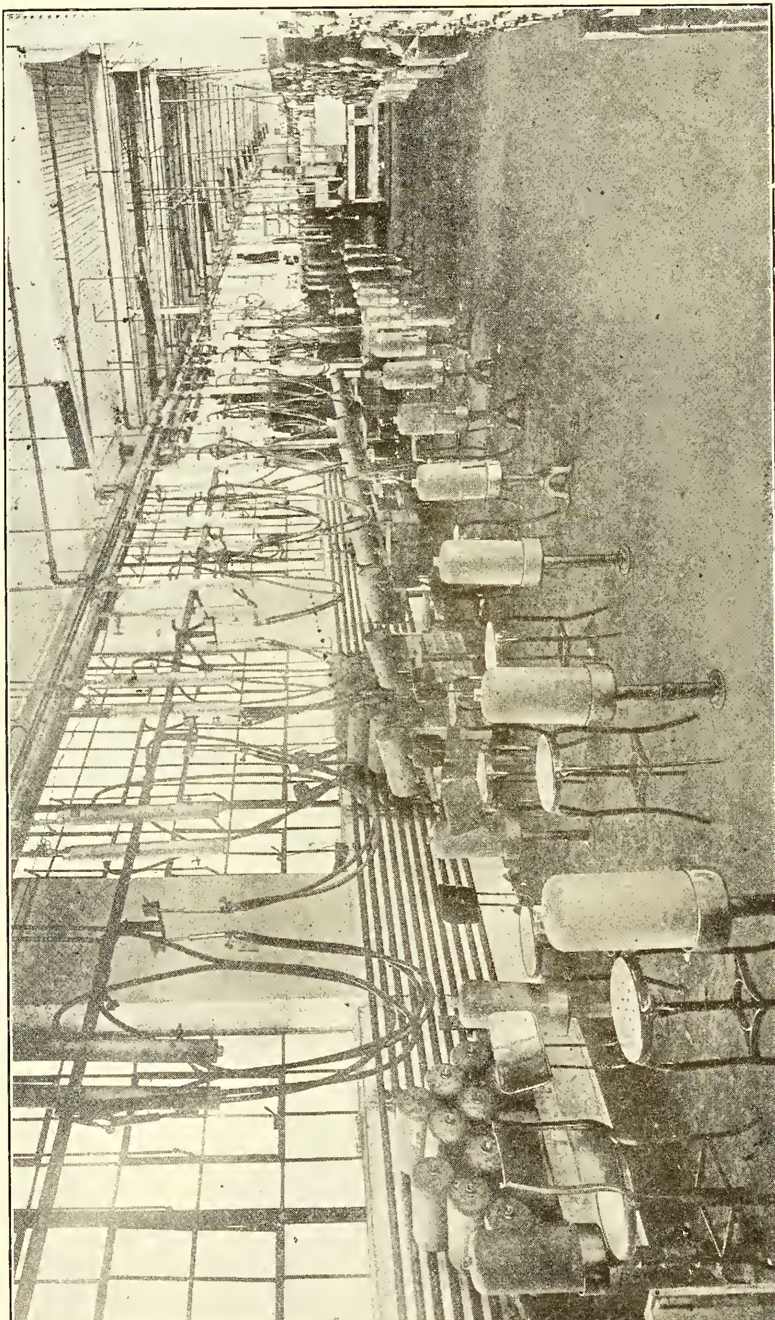


Fig. 189.—Another View of Container Welding Department.

with two jaws which are placed around the jacket for holding while being tacked. The equipment used in this operation is a miniature-style Torchweld torch, equipped with a No. 3 tip and using $^3/_{32}$-in. Norway welding wire.

"After being tacked, the cylinder is placed in another fixture, and the bottom of the jackets are welded to the jacket flange on the cylinder. The fixture employed in this operation is a fork made of steel $1\frac{1}{2}$ in. wide, so shaped as to fit the top of the cylinder and thus keeping it in an inverted position. Welding the bottom first was considered to be an advantage as the

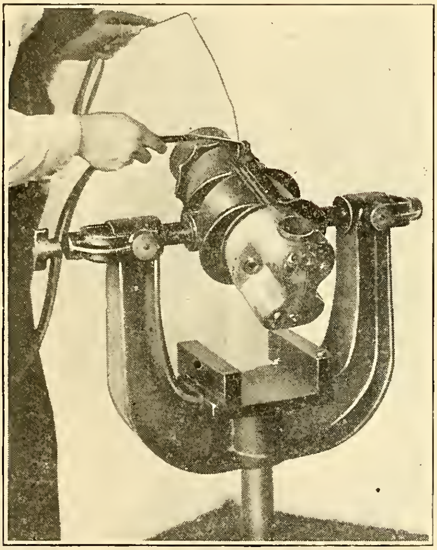


FIG. 190.—Tacking Jacket for Liberty Cylinder.

heat applied at that point had a tendency to draw the jackets closer together. It was also considered advisable to leave an opening between the jacket halves about $^1/_{16}$ in. to $^3/_{32}$ in. to take care of the contraction which the different jacket-welding operations tended to produce.

"The cylinder was next placed in a horizontal position on a cast-iron table, and the jacket-side seams were welded. The welds were started from the bottom proceeding upward to the portholes. The cylinder was then placed in an upright position and the top seam completed. The equipment used in this operation was a miniature Torchweld torch equipped with a No. 2 tip and $^1/_{16}$-in. Norway welding wire.

"The next operation was to weld the jacket around the two spark plugs, valve guide and camshaft housing bosses. The fixture employed in this operation carries a pilot upon which the cylinder can be turned circularly. The equipment used is the same as before except that a No. 3 tip was found best.

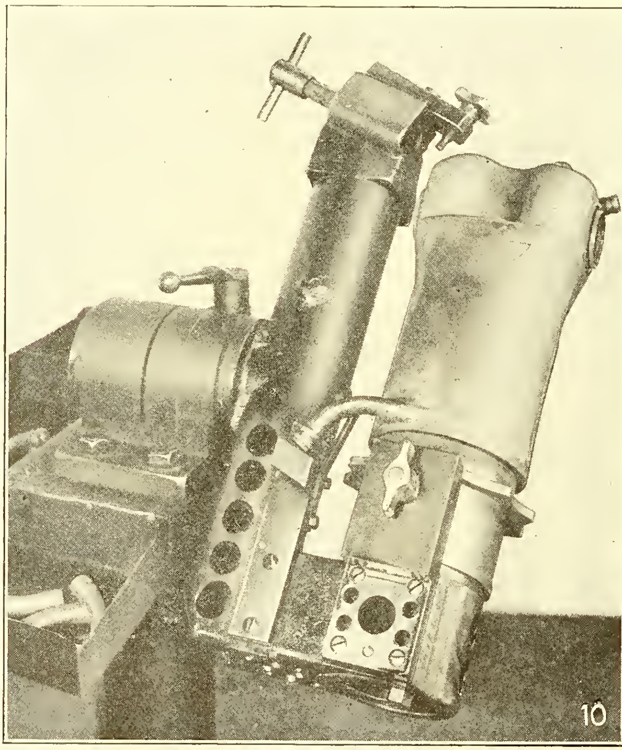


Fig. 191.—Welding the Inlet Pipe.

"Next came the welding of the jacket around the porthole flange. The fixture used in this operation consists of a standard with a revolving cradle to lay the cylinder in. The revolving motion of the cradle, together with the varying height of the standards, gives the operator easy access to weld. The equipment used is a No. 1 Torchweld torch equipped with a No. 3 tip and $^1/_{16}$-in. Norway welding wire.

"The next operation consists of welding both water pipes to the jacket and the jacket seams between the valve guide and porthole flange. This is shown in Figs. 191 and 192, both inlet and outlet being handled in the same fixture. This fixture is equipped with two devices for holding the water pipes in their proper position while being welded and is so arranged that it can be oscillated to suit the position in which the operator

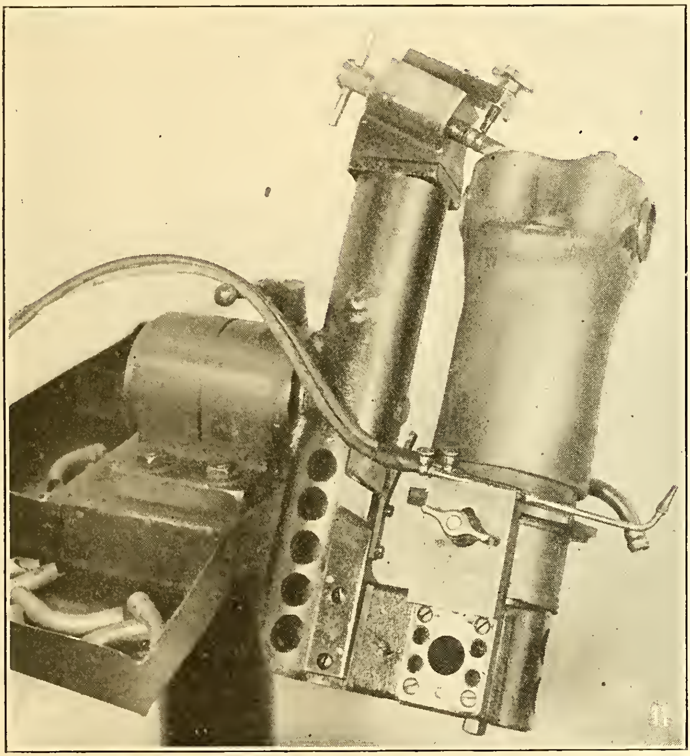


Fig. 192.—Welding the Outlet Pipe.

is welding. The cylinder is located by a flat clamp which locates the flat on the cylinder bolt flange in proper relation to the pipe-holding devices.

"The jacket seams are welded first, followed by the water outlet pipe. In these two cases, the cylinder is welded in an upright position. The locating clamp on the bolt flange flat is then released and the cylinder given a half-turn to the opposite flat. The inlet pipe is then placed in its holding device and welded with the fixture in a semi-horizontal position to suit the welder.

"The cylinder is then removed and the water pipes inspected for proper location. If it is passed, the cylinder is hammered with a rawhide hammer to remove scale and loosen any poor weld, after which it is tested for leaks. If leaks are found, they are repaired by expert welders and returned for re-inspection."

WELDING FIXTURES FOR MAKING MANIFOLDS

Writing in the *American Machinist* for March 25, 1920, C. C. Phelps says: "Several ingenious fixtures are employed to great

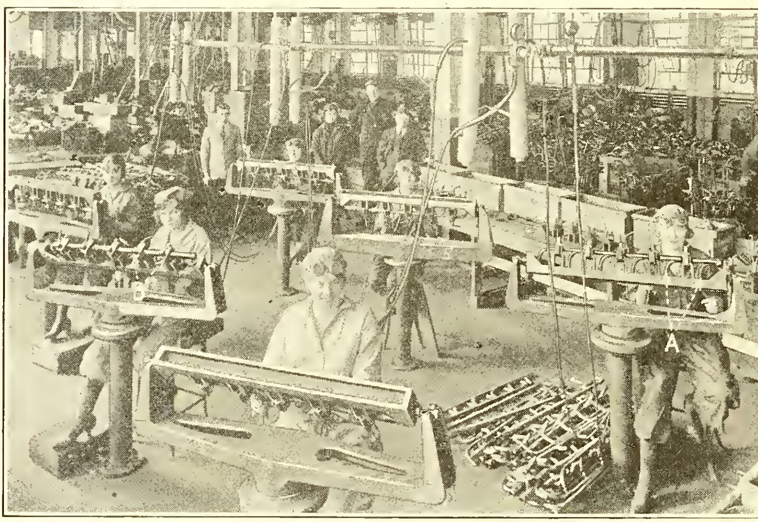


FIG. 193.—Fixtures Used in Welding Liberty Motor Manifolds.

advantage in manufacturing manifolds for the Liberty engines by means of the oxy-acetylene process at the plant of the Ireland & Matthews Manufacturing Co., Detroit, Mich. The fixtures were designed in accordance with plans furnished by the engineering department of the Oxweld Acetylene Co., Newark, N. J.

"In assembling the manifold parts in the fixture, Fig. 193, the five branch inlets are first mounted on their respective pivots *A* in the bed of the fixture; the trunk of the manifold is then placed above and in contact with the branch lines, so that the openings in the trunk coincide with the ends of the branches, and, finally, the five hinged clips *B* are swung into position and clamped down on the assembled manifold by means of the hand clamps. The end of the trunk is bent to serve as one of the inlets and this end in turn is inserted over the end pivots. The fixture shown in Fig. 194 serves to hold the assembled parts in perfect alignment.

"The fixture proper is suspended at the ends to permit com-

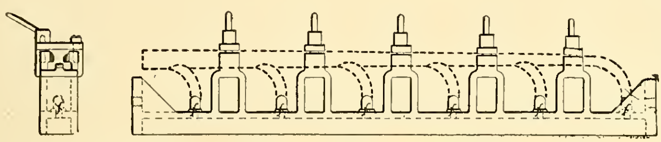


FIG. 194.—Details of Fixture Proper. Assembled Manifold Indicated by Dotted Lines.

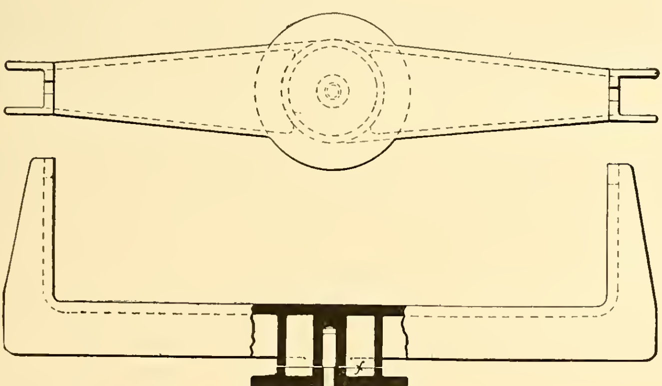


FIG. 195.—Details of Swing Support for Manifold Welding Fixture.

plete freedom of rotation, and the points of suspension are so located that the device will be in balance when containing the tubing. The support for the fixture, Fig. 195 is mounted on a pedestal in such manner as to allow rotation in a horizontal plane. Thus the operator is enabled to shift the work so that the torch flame can be applied in the most advantageous manner at all times. Fig. 196 shows the complete manifold.

"During the war this company manufactured various kinds of tubes and manifolds for Liberty and Le Rhone engines, bombs, gas shells, floats for the Navy and poison-gas tanks. When it is considered that the company had no welding equip-

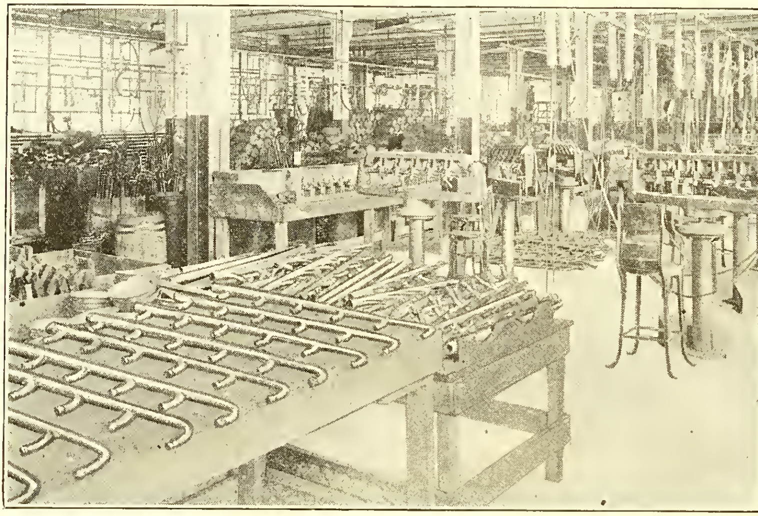


Fig. 196.—Completed Manifolds for Liberty Engines.

ment prior to May, 1918, great credit must be given to the inexperienced girl operators and the equipment that produced such results."

CHAPTER XIV

WELDING MACHINES

Gas-torch welding machines with automatic feed are used for a large variety of work, although straight-seam welding is the more common. In this latter class of work are included sheet-metal-cylinder side-seam welding and pipe or tube welding.

A welding machine, known as the Duograph, is shown in Fig. 197. This machine was made by the Davis-Bournonville Co. and was especially designed for welding the seams of steel drums or containers, insuring a mechanical weld uniform in appearance and efficiency. It comprises a turret-top holding device with water-cooled arms and clamps for holding the steel drums in position, permitting the work being placed in position for welding on one set of arms while the work on the opposite set of arms is being welded. The turret top is then swung half around, the welded work removed and another job set up.

The gas-torch carriage is moved forward at a fixed speed by power, belt driven, and is reversed by means of a hand-wheel when the weld is finished. Various speeds for different thicknesses of metal are obtained by the use of cone pulleys. The carriage is fitted with two torches—one above, the other below—as shown in Fig. 198, for welding both sides of the seam simultaneously. For very light welding, one torch only is required. Water-cooled welding torches are used. The No. 1 machine will weld a 36-in. seam, and will take containers from 12-in. to 36-in. in diameter. The No. 2 machine welds a 54-in. seam. An average speed of welding of 18-in. per minute is obtained on 16-gage sheets.

Fig. 199 is a close-up of a man putting a sheet-metal drum into position on one of the turret arms. Fig. 200 shows the drum clamped down and swung into place ready to be welded. This illustration gives a good idea of the operating mechanism.

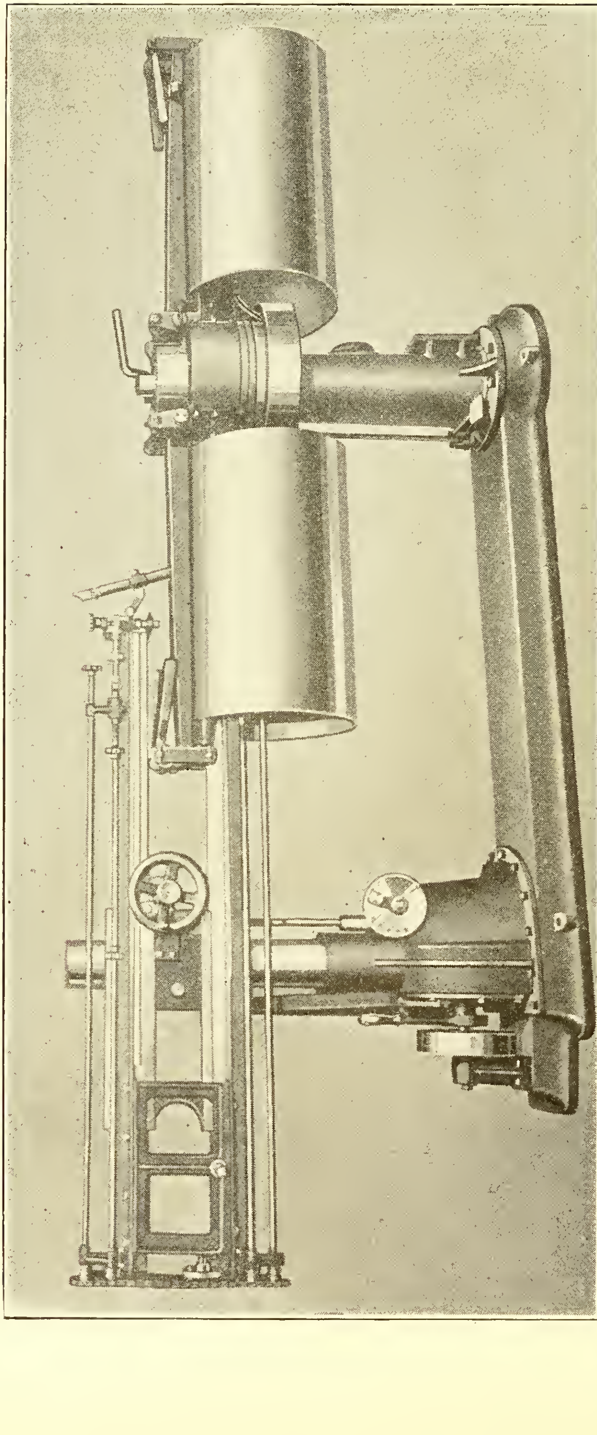


FIG. 197.—Davis-Bournonville Duograph Welding Machine.

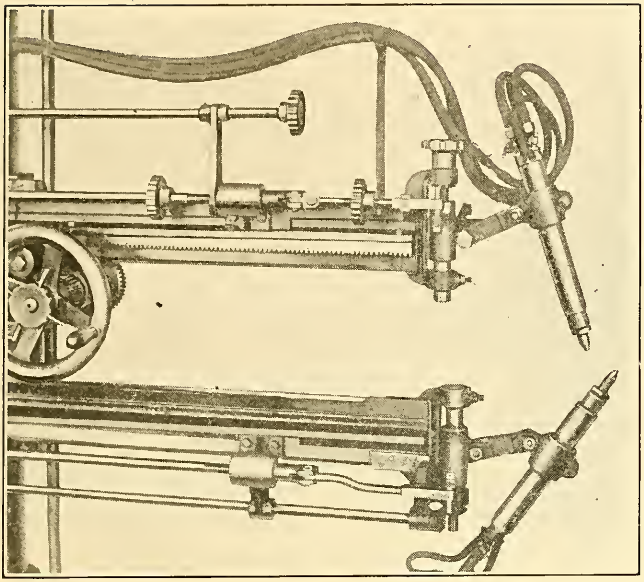


Fig. 198.—Torch Arrangement on the Duograph.

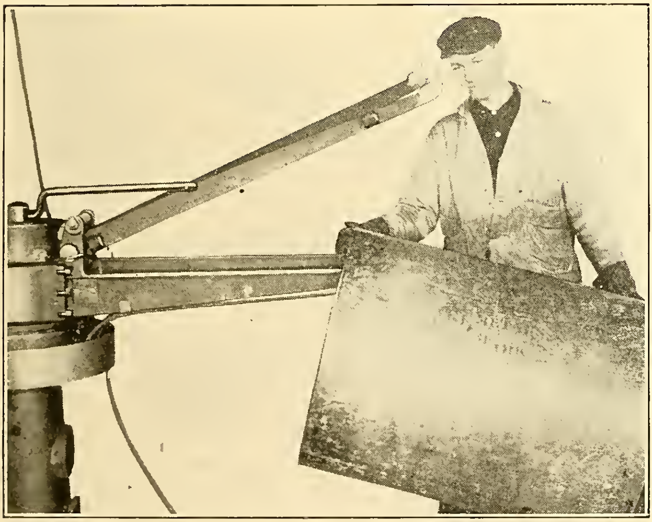


Fig. 199.—Putting a Drum Onto a Turret Arm.

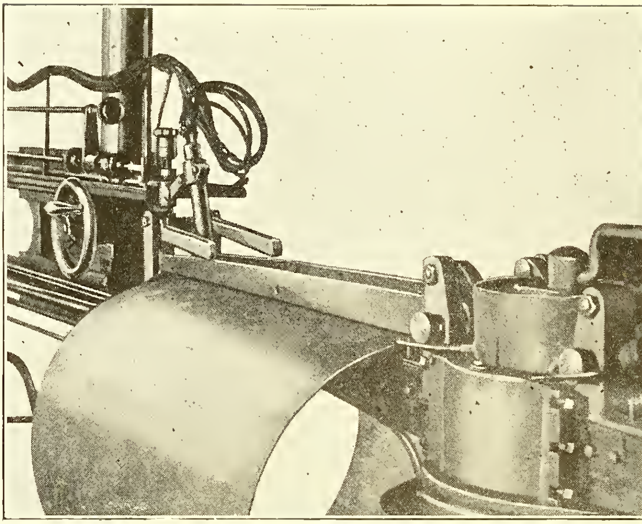


FIG. 200.—Drum in Position Ready for Welding.

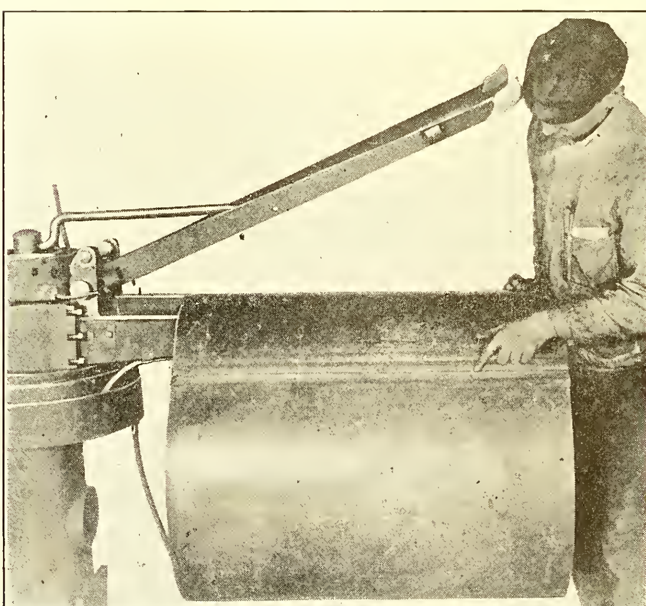


FIG. 201.—The Finished Seam Weld.

Fig. 201 shows the seam weld completed and ready to be removed.

A much simpler machine is shown in Fig. 202. The operation of the feeding mechanism is obvious.

A smaller, though very similar machine, is shown in Fig.

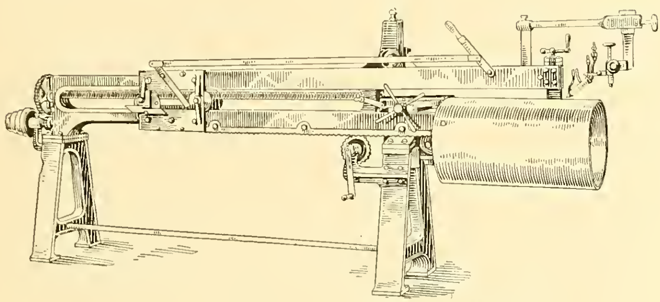


Fig. 202.—Heavy Drum Welding Machine.

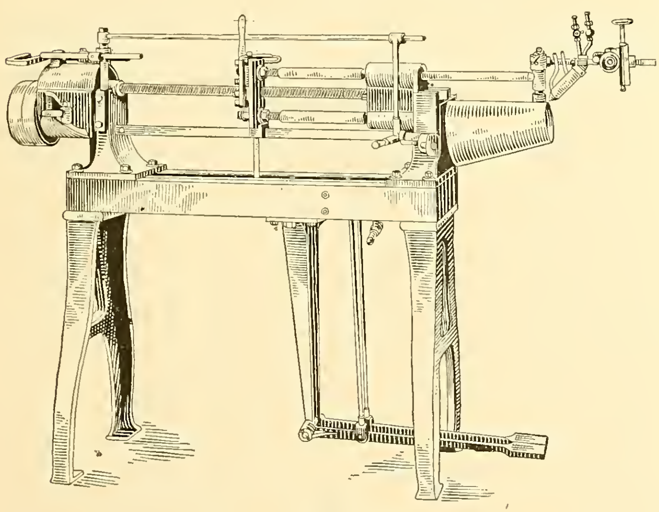


Fig. 203.—Light Seam Welding Machine.

203. While the work shown in position is cone shaped, cylinders may be held as well.

The machine shown in Fig. 204 is for welding bottoms onto tea kettles, cans, drums or other circular work. The machine is so made as to allow for a considerable range of adjustment for different sizes of work.

The last three machines mentioned were designed by Linus Wolf, of the Thermalene Co., Chicago Heights, Ill.

A machine developed at the plant of the Edison Storage Battery Co., Orange, N. J., for welding bottoms in storage-battery cases, is shown in Fig. 205. This machine was first described in the *American Machinist*, Aug. 10, 1911. The bottom

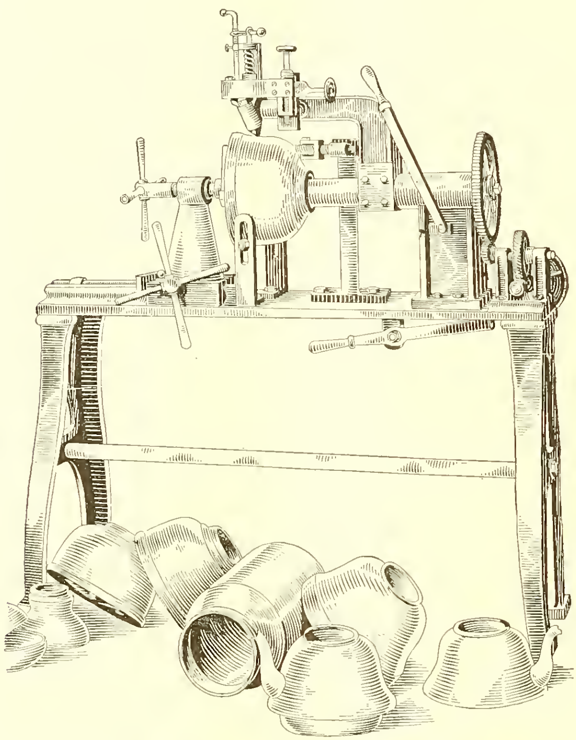


FIG. 204.—Machine for Welding Circular Seams.

to be welded in is made of sheet steel with upturned edges. A four-part expanding form is placed within the edges of the bottom and locked by turning down the screw shown in the center of the case. With the bottom and expanding form in place as shown, the case is "shrunk" to it and sized by turning the eccentric lever *A*. The gas torch *B*, which is hinged at *C*, is then swung down into welding position and so set as to throw the flame correctly onto the upturned edges of the bottom and the case. The motor is then started and the feed thrown in by means of lever *D*.

This lever operates a clutch on a shaft carrying a pinion meshing with the oblong gear on the bottom of the frame which

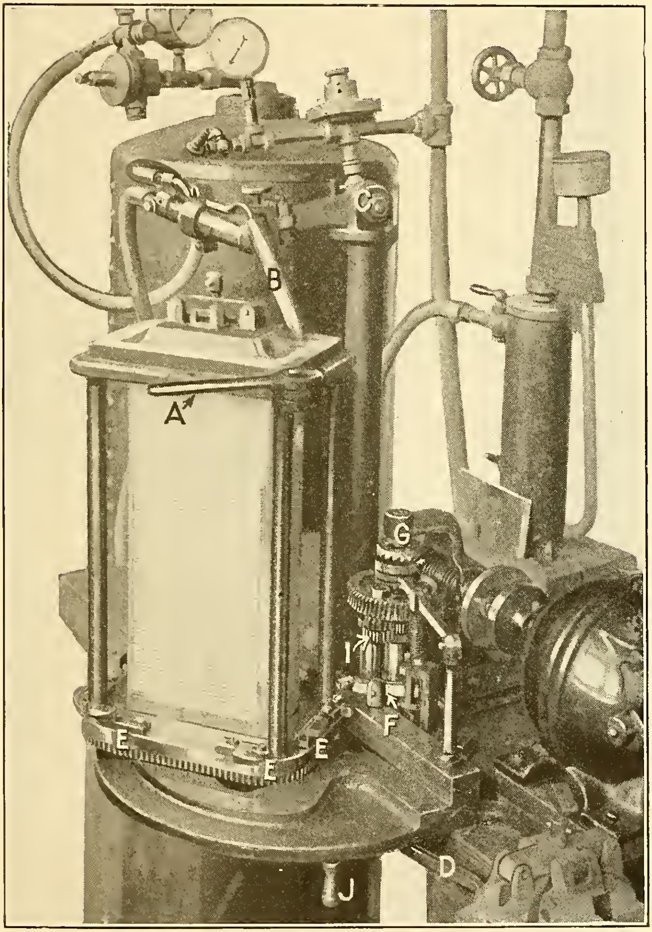


Fig. 205.—Machine for Welding Oblong Seams.

supports the case. This moves the frame and the seam to be welded along under the welding flame. When a corner is reached the trip *E* throws the lever *F* and slips the clutch *G* into contact with the upper teeth, increasing the speed of the driving pinion so that the seam being welded moves at the same speed under the flame while turning the corner as while being driven along the straight seam. As soon as the corner has been turned the lever *F* is forced down by another trip and the sun-and-planet gearing *I* again comes into play, giving a slower movement as the straight part of the seam is fed under the flame.

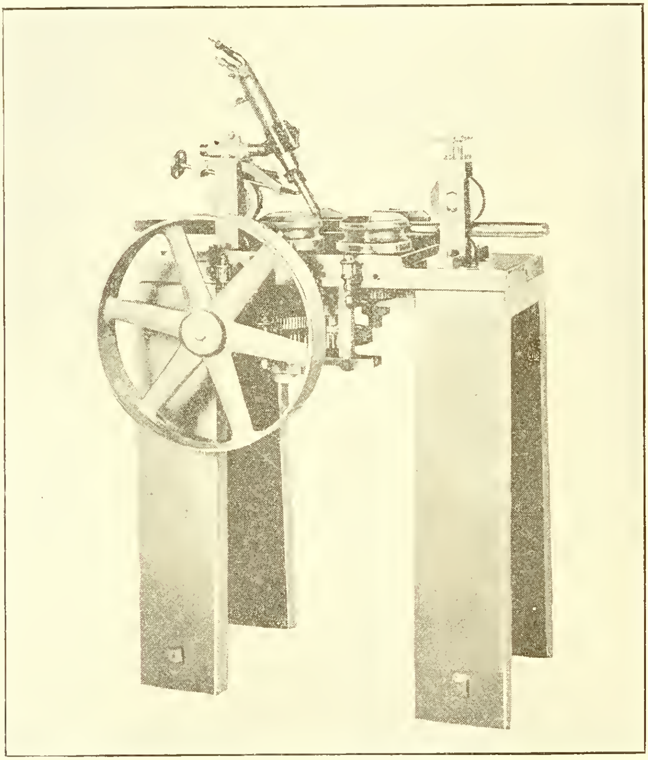


FIG. 206.—Single-Torch Tube Welding Machine.

For bringing the mechanism back to the starting point, the handle *J* is used.

A single-jet tube welding machine made by the Thermalene Co., is shown in Fig. 206. Views of a double torch machine made by the same concern, are shown in Figs. 207 and 208. In a general way, these are typical of all machines designed to butt-weld formed tubes.

TUBE WELDING BY THE OXY-ACETYLENE PROCESS

Writing in the *American Machinist*, Nov. 13, 1919, F. M. Smith, Chief Engineer of the Oxweld Acetylene Co., Newark, N. J., says: "Tubing, considered merely as a structural shape,

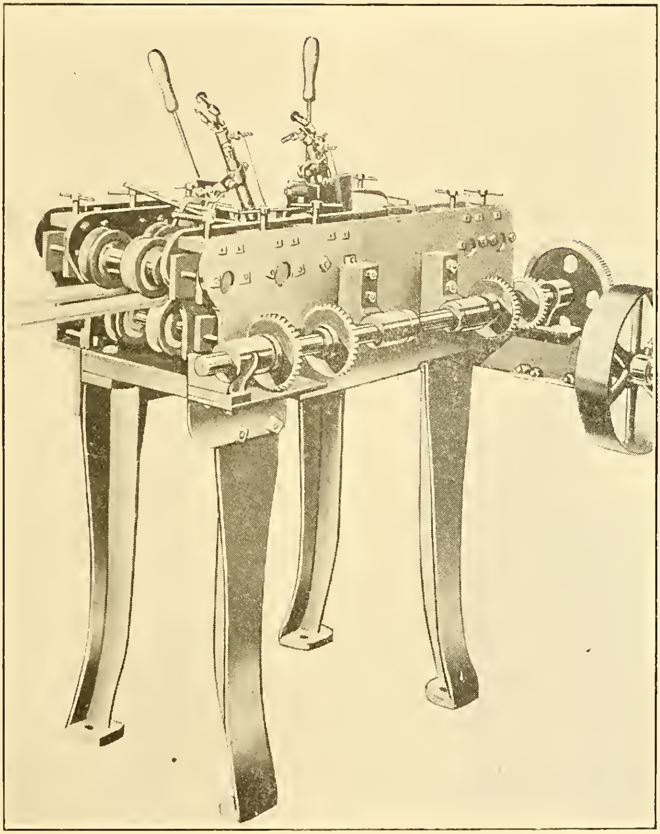


FIG. 207.—Duplex Tube Welding Machine.

has the greatest strength in compression and bending to be obtained from any shape of equal cross-sectional area. Likewise, it is one of the most convenient shapes known. In large work this fact has been applied for years in the use of round cast-iron columns and standard commercial wrought-iron pipe of various weights, but until the advent of welded tubing nothing but drawn seamless tubing was available for weights lighter than pipe and its price has been prohibitive for ordinary purposes.

"When the oxy-acetylene welding process offered a means of producing the substitute for drawn seamless tubing in the form of welded tubing of thin gage, numerous manufacturers were so well impressed with the possibilities of this line of work

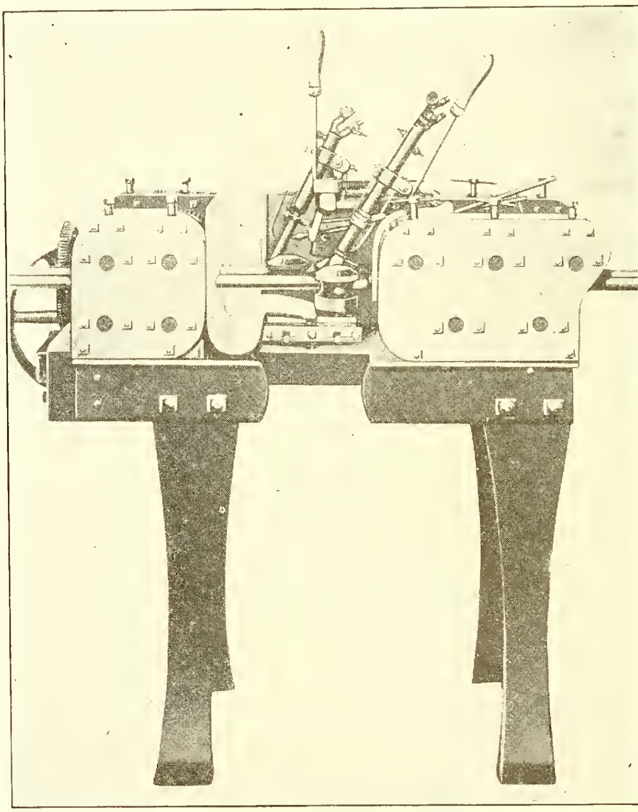


Fig. 208.—Another View of Duplex Machine.

that they went into it on a large scale. As a result, the product of the oxy-acetylene tube-welding process is of such excellent quality and is produced so much cheaper than drawn seamless tubing that it is rapidly superseding the latter form of tubing for very many purposes.

"Tubes welded by the oxy-acetylene process are almost invariably butt-welded; that is, in the tubes as formed up, the square edges lie butt to butt. The heat is applied to the seam only and must be of an intensity to raise the edges immediately under the flame to the fusing point. The edges are then pressed together while in a molten condition and flow into each other, forming a true and homogeneous weld. The weld may be upset or reinforced, if so desired, to a greater thickness than the original tubing wall by compression of the seam at the point of weld.

''As the uses of tubing are principally structural, the material from which it is made is usually low-carbon steel, although this is not used as universally as might be expected because old high-carbon rails make an excellent and comparatively cheap raw material for the manufacture of tubing by the hot formed process, where a smooth and polished surface is not required.

''The low-carbon steel tubing may be made from either hot- or cold-rolled stock. By far, the largest amount is made from cold-rolled sheet on account of its smooth finish and good appearance. Other metals can be machine-welded satisfactorily, but where they are ductile as in the case of brass and copper, it may be cheaper to make them by seamless drawing.

''Low-carbon steel us usually purchased from the mills in the shape of strips or sheets which can be rolled and sheared accurately to the required dimensions. Gang shears reduce the sheet to strips of accurate width in one operation. The tubing is formed cold by first rolling it to semi-circular form and closing it in to the circular form either in a conical drawing die or by further reductions in size between rolls, the latter being generally the preferred process because it eliminates subsequent warping at the seam.

''Rails from which high-carbon tubing is usually worked up are broken into the correct lengths to produce a 50-ft. skelp, heated in an ordinary heating furnace and broken down to rectangular section of the desired gage and width by a series of rolls of the usual rolling-mill type. The skelp is then passed, while still hot, through a pair of rolls which form the section to a half circle and force it through a conical die which draws in the edges to the final complete circular section required for tubing.

''Owing to the inaccuracies of this type of mill, the gage and width of the skelp, which latter dimension determines the diameter of the tubing, cannot be held to any close accuracy, and, consequently, this type of tubing is used only for purposes where exact size is not important, such as bedstead frames, handles for tools, and the like.

"Machines for tube welding consist, in general, of a table with frame, or housings, upon which is mounted the feeding

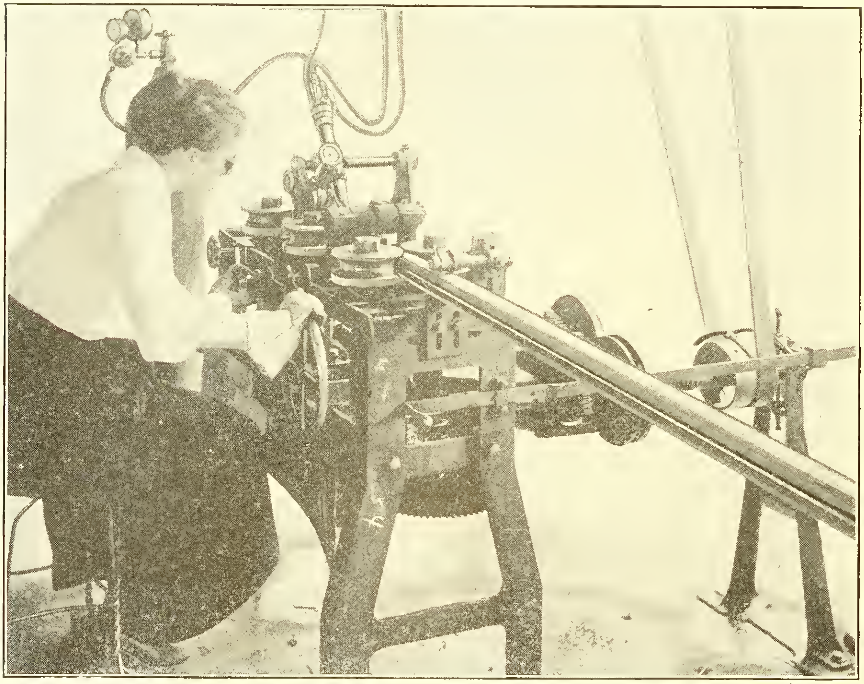


FIG. 209.—Feeding End of Tube-Welding Machine With Oxweld Multiple-Jet Gas Torch.

mechanism and its drive; above this, a gas-torch holder equipped with a horizontal adjustment at right angles to the seam, another in the direction of the axis of the torch and a hinged arrangement by which the torch may be lifted away from the work.

"There are two general types of feeding mechanism, one of which, covered by the Lloyd patents, consists of a continuous or endless-chain arrangement. Two chains are required, one on each side of the tube, each link carrying a block with a groove in its face to fit the tube. Two corresponding blocks, when moved forward between rolls upon which the endless chains are mounted, catch the tube between jaws and carry it

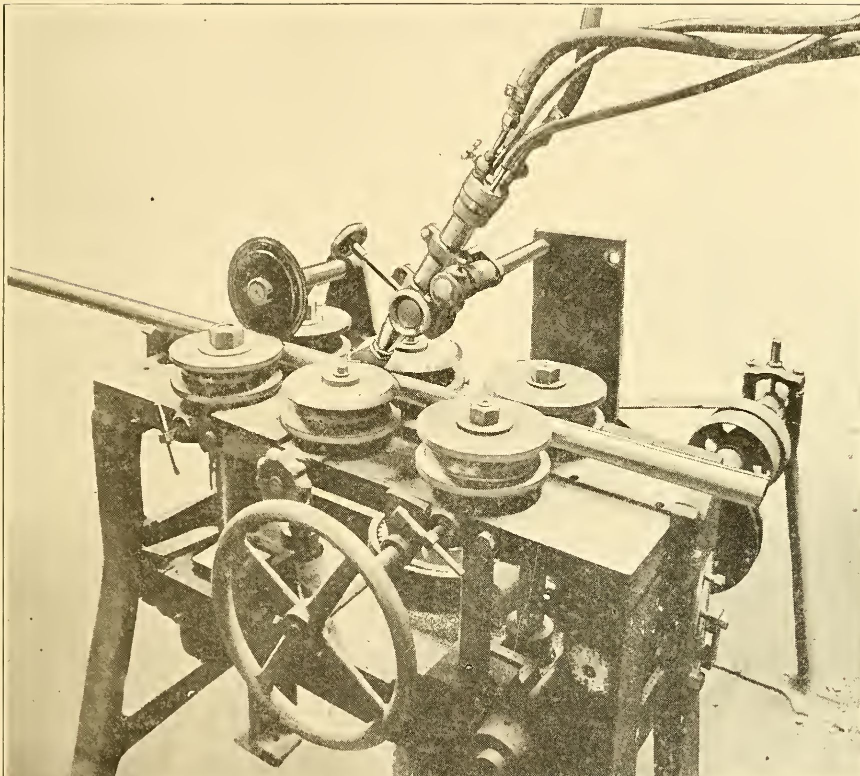


FIG. 210.—The Left Set of Rolls Feed the Tubing while the Spreader Disk Opens the Seam Slightly.

The central rolls hold the tubing to specified diameter while welding and the right set of rolls act solely as guides.

forward at a uniform rate of speed, at the same time compressing the seam the desired amount to secure a satisfactory weld.

"**How Rolls Are Arranged.**—The other, and more generally used method, shown in Figs. 209, 210 and 211, employs two trains of rolls, three on each side, having grooved surfaces to fit the tubing. The middle pair, known as the welding rolls, are chamfered away on the top side to allow the welding flame to work in between them. The forward and rear pairs are used merely as feed and guide rolls. In order that different sizes may be welded on the same machine, rolls having grooves of varying depth are provided to fit the various diameters of tubing to be welded. Provision is also made for opening and closing the rolls to get heavier or lighter welds.

"Experience has shown that to secure an even and smooth seam, it is necessary to counteract the effect of expansion and

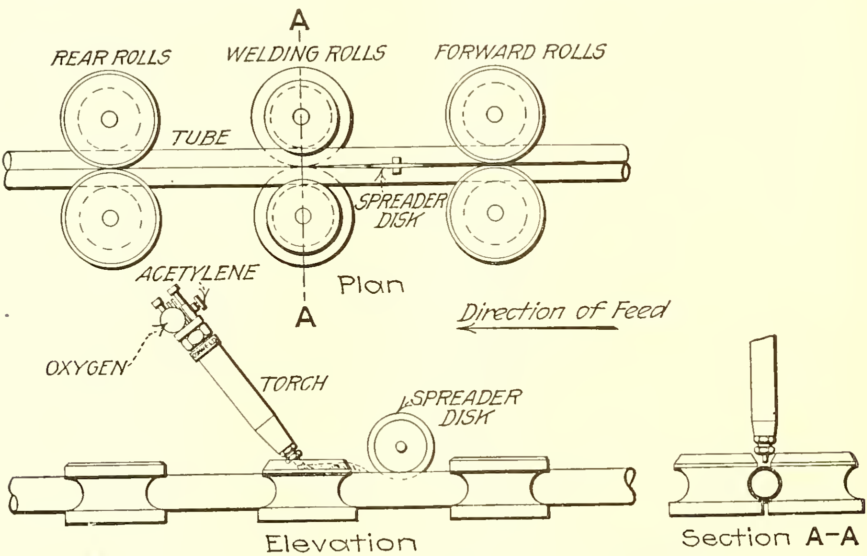


Fig. 211.—Diagram of Arrangement for Tube Welding.

contraction by spreading the seam open $^1/_{32}$ in., more or less, about 6 in. ahead of the welding rolls. This is generally accomplished by mounting a thin disk abreast of the forward guide rolls at such a distance that its lower edge will enter and spread the seam apart the necessary amount to secure this smoothness of weld. This disk also answers the purpose of aligning the seam under the flame.

"The drive should be arranged to give different speeds in order that the machine may be used on different types of welding, but should be of such pattern that when once the speed is set, it will remain closely uniform.

"There are two general types of oxy-acetylene torches in use, corresponding to the two schools of oxy-acetylene practice; namely, the low-pressure and pressure types. The low-pressure type is very successful in welding operations owing to the 'softness' of the flame due to the low velocity of the heating gases. It also implies efficiency, as the gases passing over the metal at a low velocity have more time to give up their heat. The uniformity of the low-pressure flame is because the acetylene is supplied from a gas bell at an even pressure.

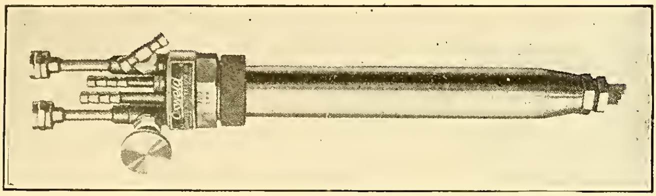


FIG. 212.—Four-Jet Type W-5 Water-Cooled Welding Torch.

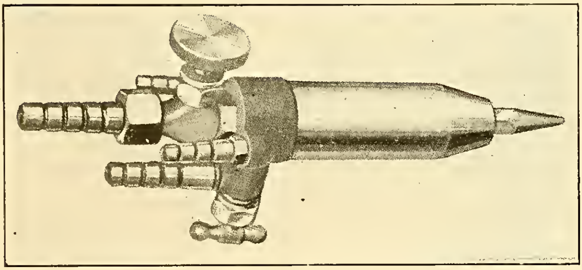


FIG. 213.—Oxweld Type W-8 Single-Jet Water-Cooled Welding Torch.

"In the welding of heavier gages, more heat is required than for lighter work and this is secured by arranging a variable number of flames in a line progressively along the seam to be welded (see Fig. 212). The forward flames successively raise the temperature of the tube to such a point that the last flame will fuse the metal just abreast of the welding rolls which compress the fused edges together, forming a perfect weld. For welding tubing of 14 gage, as high as nine or ten flames have been successfully employed and with this number of flames a welding speed of 5 ft. per minute can be obtained. With such a concentration of heat, water-cooling is necessary to maintain a uniform flame and eliminate backfiring or ignition of the gases within the tip. The torch proper is always water-cooled to secure uniformity of flame and for the comfort of the operator. For the heavier work, mentioned above, the possibilities range down to 22- or even 24-gage metal, upon which a single flame torch, Fig. 213, may be employed. Short samples of welded tubing are shown in Fig. 214.

"After welding, if it is desired to secure a very exact diameter, either externally or internally, this is accomplished by drawing. The operation is performed on the draw bench which consists of a long frame, usually horizontal, at one end of which is a

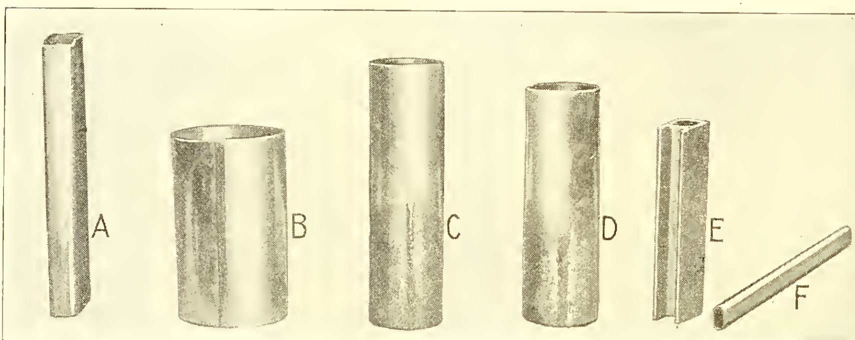


Fig. 214.—Samples of Tubing Welded by the Oxy-Acetylene Machine Welding Process.

A—Cartridge case. *B*—Tubing as welded. *C* and *D*—All traces of welding eliminated by grinding and polishing. *E* and *F*—Wind-shield frame and wedge.

die of chilled cast iron or hardened steel. This die must be of the correct diameter and smoothly polished to produce the correct finish. It may be either externally or internally applied. When used on the inside of the tubing, it is known as a 'triblet.' The tubing is entered into the die or over the triblet; the end is crushed to secure a grip for the drawing mechanism, which is located at the opposite end of the bench, and the tube is then drawn through the die producing the correct size and a very smooth finish. Suitable lubricants must be applied to the surfaces of the tubes during this process.

"Where only a bright finish, without exact diameter, is required, drawing is not employed—ordinary flashing or polishing methods being sufficient. If the tubing is to be painted, or for some other reason high polish is not necessary, it is often satisfactory, if a smooth weld is secured, to use the tubing just as it comes from the welding machine.

"The principal difficulties encountered in tube welding are to secure a uniform, continuous and neutral flame and to feed the tubing under the torch at a correct and uniform rate of speed at the most effective distance from the tip with the seam exactly in the flame.

"The first difficulty is largely solved by using the proper torch. The second difficulty is mechanical and can only be eliminated by standardizing shop conditions.

"The stock strip must be held to exact width if a uniform diameter and thickness of weld are to be produced. The tolerances are determined by experience, but once set should be strictly held to. Burrs on the sheared edges must absolutely be eliminated as these get into the seam and hold it open causing 'skips.' When the strip is formed into tubing, care must be taken to secure a very exact adjustment of the rolls and dies or otherwise the seam in the tube will assume a spiral shape, causing difficulties in guiding the seam exactly under the flame. If the flame does not play exactly upon the seam, only one side of the seam will be fused and the weld will 'skip' until the flame is correctly adjusted. Lost motion in the feed rolls and in the adjusting mechanisms of the torch holder will invariably aggravate this difficulty.

"In the early days of this art, when manufacturers were content with speeds of 2 to 3 ft. per minute, it was possible for the operator to adjust his flame from side to side, follow the irregularities in the seam, and to slow down his machine when the weld showed a tendency to skip. With the speeds attained in modern production, from two to four times as fast as formerly, this is no longer possible. The operation progresses so rapidly that it is humanly impossible for the operator to adjust his machine to changing conditions and, in consequence, if the seam is not perfectly true the operator must necessarily fail to get a continuous weld and even in attempting to do so he will constantly slow down his machine, thus limiting the quantities of tubing produced.

"The successful manufacturers have, therefore, applied the well-known principles of scientific management to this problem and by studying the conditions under which the forming and welding are done have succeeded in so standardizing their product that the welder is not required to do anything but start the tube into the machine and keep the torch lit and the tip free from accumulations of slag and dirt. The tubing is required to come absolutely uniform in diameter and straight in seam. The set of the rollers, speed of welding and pressures of the gases in the torch are adjusted by the foreman or tool setter in charge to predetermined standards which are not allowed to be changed by the operator. If, with the machine as delivered to the operator, he cannot secure good tubing, the machine is shut down, the trouble discovered and the proper remedy applied.

"By the application of such methods as these and with the full coöperation of the manufacturer of oxy-acetylene apparatus, it is not remarkable that great progress in the development of the art of oxy-acetylene tube welding should have been made within so short a time."

CHAPTER XV

CUTTING WITH THE GAS TORCH

The gas-torch cutting process consists of heating a spot of the metal to be cut to a good red heat and projecting on it a jet of oxygen. This causes the metal to burn away, a stream of slag running out of the kerf thus produced. Cutting is not melting, in the ordinary sense, although since the heating flame is the only visible agent, such might be the beginner's conclusion. It should be remembered that the heating flame is only used to make the metal hot enough to oxidize easily.

Metals whose oxides have a lower melting point than the metal itself can be cut by the gas torch. Such metals are wrought iron and steel. Where the oxide has a higher melting point than the metal, cutting with the gas torch is either impossible or not satisfactory. Such metals are copper, brass, aluminum, cast iron, etc.

A big factor in successful cutting is to properly support the body and torch to as great an extent as possible commensurate with the steady forward movement of the torch. The position must be an easy one, as muscles under tension will cause vibrations and these are fatal to good cutting. An ideal position for an operator, is shown in Fig. 215, although in actual, every-day practice one usually has to be satisfied with less desirable conditions.

Theoretically, with the cut once started the oxygen jet alone should be sufficient to keep up the combustion, as there is considerable heat generated in the process. However, the stream of oxygen is small and the burning metal confined to a very narrow slot, and scale, dirt, sand, blowholes and other things interfere to prevent the continuation of the cut of the jet without an accompanying heating flame.

A cutting torch is lighted in the same way as for welding, except allowance must be made for the drop in the oxygen

FIG. 215.—An Easy Cutting Position.

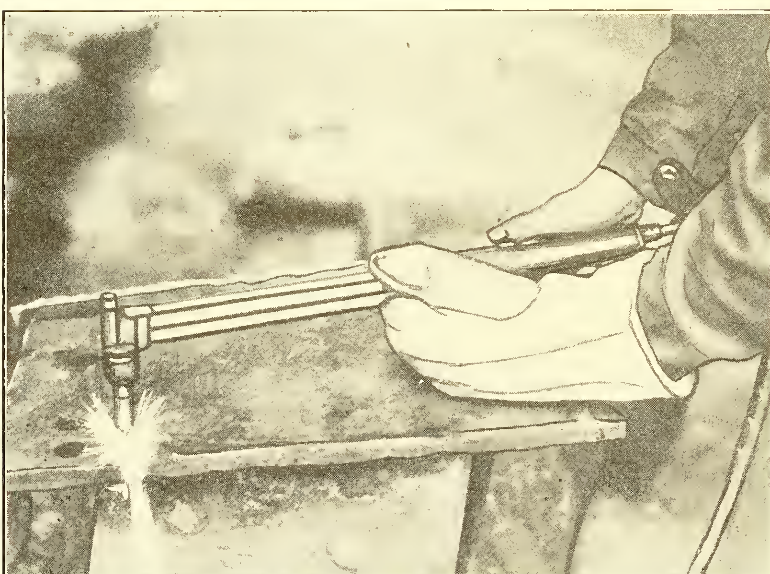


FIG. 216.—Starting a Cut With a Davis-Bournonville Torch.

pressure when the cutting jet is turned on. This allowance can be made by regulating the flame while the jet valve is open, which is done before starting to work.

When the flame is adjusted, hold the torch as shown in Fig. 216, the left hand grasping it well toward the head and the right hand on the handle with the thumb or fingers controlling the jet level valve. The metal to be cut may be a piece of

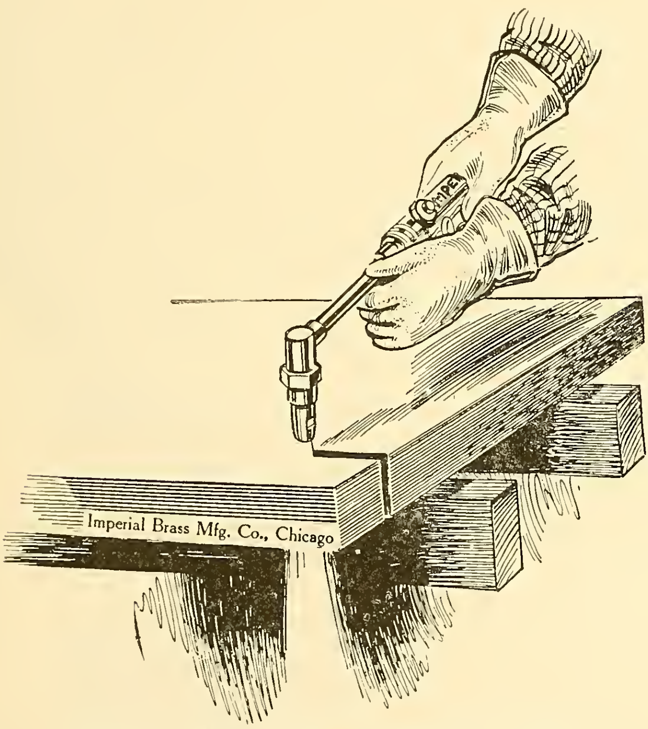


FIG. 217.—Making a Clean Cut Through a Plate.

heavy boiler plate, steel bar or structural steel. Rest the elbow, forearm or hand on the plate to steady the torch. It is usually best when cutting without a guide wheel, to arrange to cut either to the right or to the left rather than toward or away from the operator. However, an operator should learn to cut in any direction. When it is possible, always start on the edge. Hold the flame on one spot until it is a nice red, then turn on the high-pressure oxygen jet. Hold the torch steady with the luminous cone almost touching the metal, until the cut goes through. Sparks should show as in Fig. 217. If they fly, as in Fig. 218, the cut is not going through.

In the cutting of plates, it is advisable to tip the torch head in the direction of the movement, once the cut has progressed a little. This rule does not apply in the case of blowing holes in metal where the nozzle must be tipped away from the slag

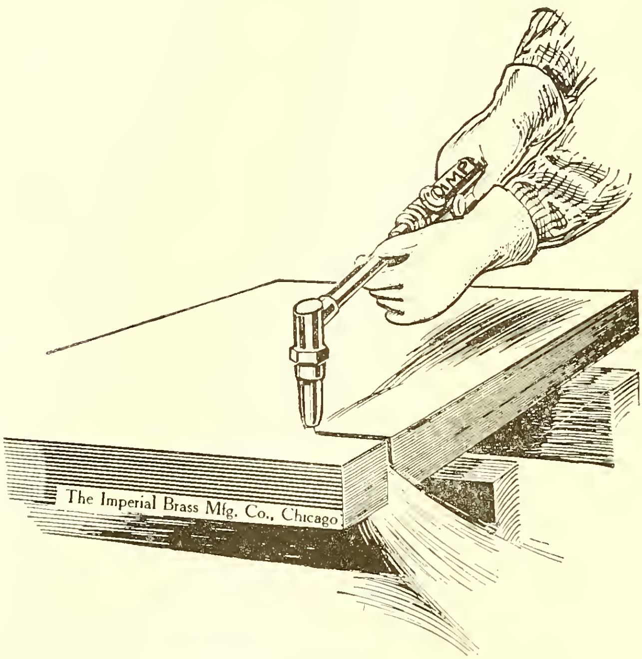


Fig. 218.—Cut Not Going Through Properly.

so that no particles will impinge on the orifices or a back pressure be created on these orifices.

If the metal is very thick, the oxygen pressure will have to be high. In beginning a cut of this type, it is necessary to blow the oxide out at the bottom before the cut has traversed very far into the body of the metal, otherwise, a pocket will be formed and it will be impossible to penetrate to the bottom of the metal. In cutting heavy material, success depends entirely upon the ability of the individual. The nozzle must be turned outward in preheating and must be carried inward with the tip gradually moving to a vertical position and finally forward as the cut progresses. In blowing holes, as in Fig. 219, the metal must be blown away from the tip, and to accomplish this

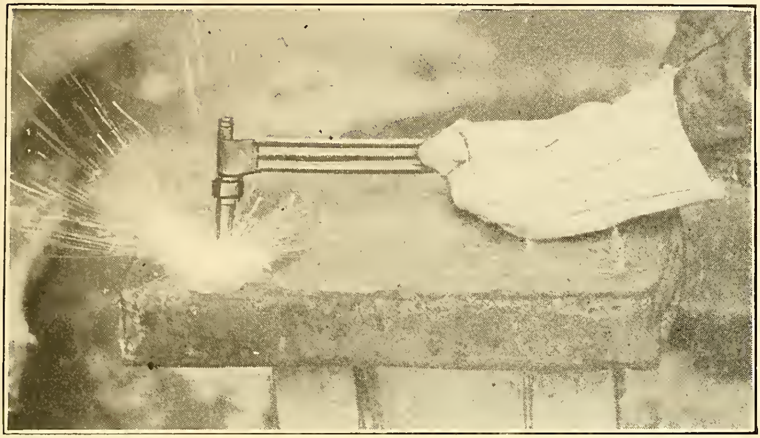


FIG. 219.—Blowing a Hole Through a Plate.

FIG. 220.—Cutting Off a Rivet Head.

it is advisable to begin with a very wide kerf, produced by rapid movement of the torch sideways while carried away from the origin of the cut. In this way the oxygen penetrates deeper into the metal while the torch is moving, until, finally, the oxygen emerges at the bottom, when the torch can be brought to a final cutting position and the metal cut in any direction.

Rivet head cutting in shipyards is generally accomplished by means of a specially designed nozzle, which rests upon the plate so that the preheating jets and cutting jet will act at the base of the rivet head as shown in Fig. 220. In blowing out countersunk rivet heads, the same procedure must be followed as in blowing holes, but more precautions are necessary in order that particles of metal do not impinge on the preheating orifices and clog them or cause backfire.

The "nicking of billets" became very common during the

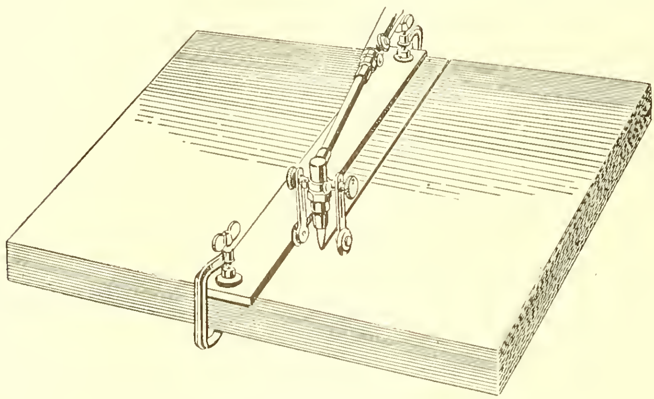


FIG. 221.—Using Rollers and a Bar Guide.

war. A narrow, shallow cut is made on one side or around the circumference of a steel section, then the billet is snapped off at the nick in a press or hammer.

When a cut must be reasonably smooth, use wheel guides, if possible. If a straight line must be followed, a bar of metal may be clamped to the work as shown in Fig. 221. A good way to both guide the cut and support the operator's hand, when cutting ship plates is shown in Fig. 222. This principle may be applied to other work.

For cutting circles, a radius attachment is used, similar to the one shown in Fig. 223. This device is made by the Carbo-Hydrogen Co., Pittsburgh, Pa., but practically every torch manufacturer makes something of the kind.

The way the cut on a 12-in. shaft looks is shown in Fig. 224. This was cut with an Oxweld low-pressure torch. The chalked

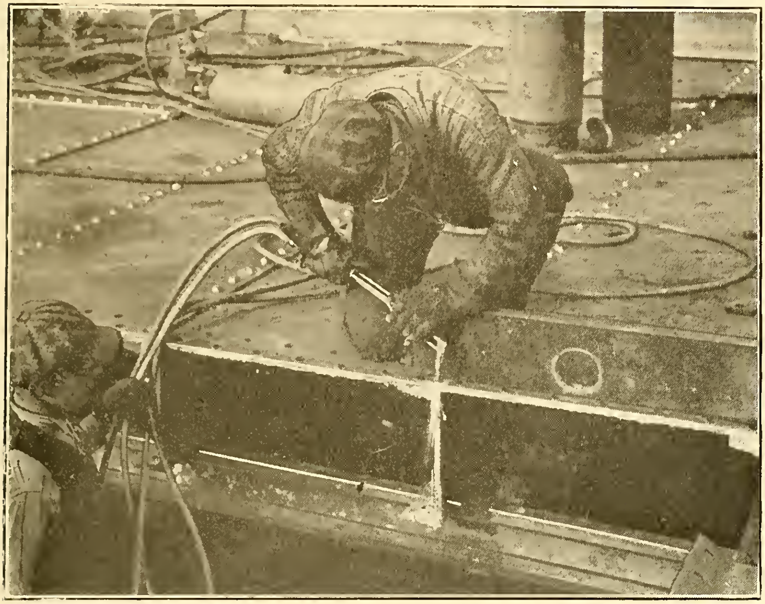


FIG. 222.—Cutting Ship Plates.

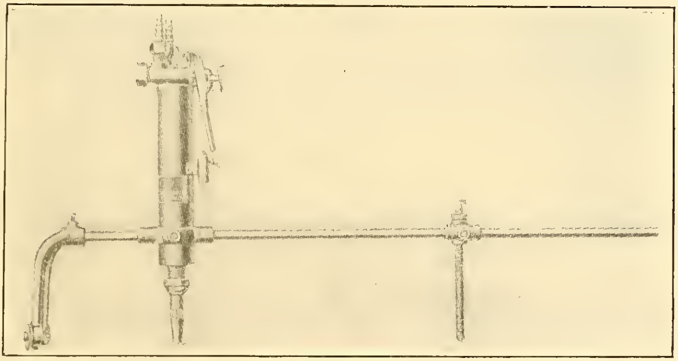


FIG. 223.—Radius Cutting Attachment for Straight-Tip Torch.

arrows indicate a blowhole and a crack which materially retarded the cutting. This cut took 3 min. 27 sec. and about 75 cu.ft. of oxygen was used. A similar cut, under similar conditions, but made without encountering any flaws in the steel, was made in 3 min. 10 sec. and 67 cu.ft. of oxygen was used.

On work 1 in. thick or over, a slot of from $^1/_{16}$ to $\frac{1}{8}$ in. is about right. For thinner stock, or when using a machine, the slot may often be reduced to less than $^1/_{16}$ in. by a skilled operator with special tips.

Flame Control.—In working hold the flame so that the end of the cone just clears the metal—do not attempt to plunge it

FIG. 224.—A 12-In. Shaft Cut with a Gas Torch.

down into the cut. When cutting two plates or more, or where there is a lap joint, remember that there is more or less of an insulation (air, dirt, etc.) between these plates and that the oxidation cannot be as fast as where only one thickness is cut. Remember that the flame does not do the cutting—therefore, work with the smallest flame possible—it means a neater cut. Keep the oxygen pressure as low as possible and yet maintain speed. A high pressure is spectacular and there are a great number of sparks, but it is not economical and a wider kerf is made. Do not use the torch with greasy gloves—a spark in combination with a leak on the oxygen supply will badly burn the hand. If a cut must be started in any place except on the edge, drill a hole or use a cold chisel and a hammer to roughen up the surface, the idea being to get an edge to quickly start oxidation.

Making a Ladle Hook.—As an instance of the many savings that may be obtained by the intelligent use of the gas-torch cutting process, the following will be of interest:

At one of the shipyards scrap ship plates are cut into special shapes for building up large hooks like the one shown in Fig. 225. These hooks are used for handling large ladles in a near-by steel mill and have resulted in a great saving.

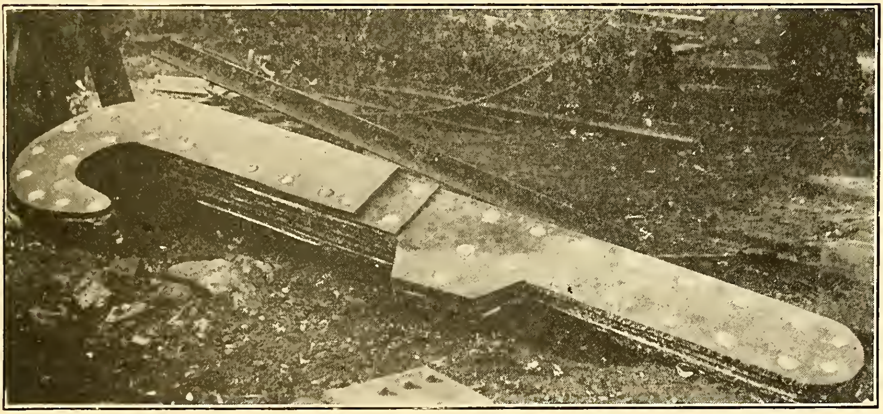


Fig. 225.—Ladle Hook Made of Torch-Cut Plates.

The hooks are 8 ft. in total length and are made up of six layers of plates which run the full length, with four short layers, all securely held together with countersunk rivets. The four inner plates are each $\frac{1}{2}$ in. in thickness. The two outer full-length plates are of $\frac{7}{8}$-in. material. Adjoining the latter plates on either side is a half-length plate $\frac{1}{2}$ in. in thickness. The hook proper is still further reinforced by two slightly shorter outer plates, each $\frac{7}{8}$ in. in thickness.

The plates are first marked with the aid of a templet to serve as a guide for the cutting torch. After cutting, they are assembled and riveted as shown in the illustration. A laminated construction of this sort is not only exceptionally strong, but is a decided economy, as it makes use of what would otherwise be waste material.

Firemen are frequently confronted with locked steel doors or barred windows. These readily yield to a properly applied cutting torch. Fig. 226 shows a fireman demonstrating how an Oxweld emergency cutting outfit may be used. The entire kit weighs 118 lb.

A very wide field for the cutting torch is in reducing scrap to workable dimensions. The figures here given regarding the cutting of scrap, are taken from a bulletin issued by the Oxweld

Fig. 226.—Fireman Demonstrating an Emergency Kit.

Co. Where costs are quoted the estimates should be about doubled for present conditions (1920).

An operator recently cut two twenty-ton steel fire boxes into scrap, prepared for the shears in twelve hours. More than 300 lin.-ft. of cut was made through $\frac{7}{8}$-in. plate (considering the mud ring and over-lapping plates). The total cost for oxygen, acetylene and labor was $24.10 per fire box—cost per ton $1.22.

In another case a locomotive boiler was cut into scrap at a total cost of $2.63, the number of lineal inches cut totaled 210 through $\frac{1}{2}$-in. plate, 9 through 3-in. plate and 172 through $\frac{3}{8}$-in. plate. This amount of cutting was completed in fifty-three minutes at a cost of 8 cents per foot for the various thicknesses. The foreman in charge of this job stated that the work done by one operator in one and one-half days would require the services of two men for, at least, a week, with ordinary working methods.

A ten-ton boiler was reduced to scrap ready for shears by one operator in nine hours at a total cost of $16.00 or $1.60 per ton.

On another piece of work, the operator cut 78 ft. of ½-in. plate in two and one-half hours. One piece of this plate, 18 ft. long, was cut in 13 min. The cost of cutting the 78 ft. was $4.25 or $0.054 per foot through the ½-in. plate at a rate of over 30 ft. per hour.

A three-ton boiler averaged $2 per ton cut in one and one-half hours. The total length of cut equaled 60 ft. 4 in. It would have cost $3 to $4 per ton to cut this boiler by hand.

A fourteen-ton boiler was cut at the rate of $1.23 per ton in nine hours and at a total cost of $17.38. One hundred and eleven feet eight inches of cut was made at the rate of $0.149 per foot.

Three fire-box boilers weighing ten, twelve and fourteen tons respectively were scrapped at the average rate of $1.40 per ton. The users of this plant state that the apparatus enables them to cut into scrap five locomotives where one was handled by the methods used before the Oxweld process was employed.

Cutting steel car frames into scrap shows equally important savings in time and money.

A five-ton car frame was cut in two and one-half hours at an average cost of $2 per ton. It was cut into 4½-ft. lengths through three and four thicknesses of plate in some parts of the frame.

A record kept of cutting about 12,000 lb. of wrecked steel car frames shows a total cost of $8.10, or about $1.35 per ton. These frames were cut into 4½- to 9-ft. lengths, in five hours.

CUTTING CAST IRON WITH THE GAS TORCH

In a paper read before the American Welding Society, April 22, 1920, Stuart Plumley and F. J. Napolitan, of the Davis-Bournonville Co., outlined some of their experiments in relation to the cutting of cast iron with a gas torch.

They said in part:

While we are rather skeptical of the commercial value of a cast-iron cutting torch, and are convinced that, financially, we shall never be repaid for the expense of our experiments, yet there are undoubtedly occasions when the cutting of cast iron would be of great value. In ordinary scrap-yard work, it is so easy to break cast iron that it would hardly be economic to use the cutting torch as for steel.

You are all aware, of course, of that application of oxygen cutting used largely in blast furnace practice, the opening of a "frozen" tap hole. You could not quite reconcile this more or less common application of the process with the pet theory that cast iron could not be cut. One of the usual methods for releasing a frozen tap hole in a blast furnace is substantially as follows: A piece of ¼-in. iron pipe with a brass handle at least 10 ft. long is attached to a manifold of several oxygen cylinders. Oxygen is delivered through this pipe at a pressure of approximately 100 lb. per sq. in. A hole is started with a star drill or diamond point, until it is about 3 in. deep. The metal adjacent the hole is heated with a fuel oil burner or by other means. The end of the iron pipe is ignited and the composite stream of molten iron slag and oxygen caused to impinge against the frozen cast iron.

A spectator to this performance of infernal fury, is readily convinced that the heat is not all due to the combustion of the wrought iron pipe, but that the cast iron is burning with a violence equal to that of steel. This reaction inspired some inventors to incorporate a device in an oxy-acetylene torch for cutting cast iron, which would feed a steel wire between the cutting jet and the cast-iron piece being cut. Ignition of the wire carried a stream of molten slag on to the cast iron and it was hoped thus to propagate the cut. In a second process, a plate of steel of a definite and predetermined thickness, was placed on top of the cast iron. It was hoped that the slag incidental to the oxidation of the steel would exercise some influence over the cast iron and enable it to be cut.

Unfortunately for those responsible for the exploitation of these devices, the inventors were more concerned with converting cast iron into iron oxide by means of the oxy-acetylene torch than they were in constructing a practical process and a practical tool. It was next proposed to simplify the reaction by supplying an apparatus with a mixture of pulverized slag and iron powder, and in fact a number of patents were issued covering various applications of such a device. Crude and elementary as such devices were, they actually produced combustion of the cast iron and went a long way in stimulating us in our endeavors to find a successful method.

Experimental work was carried on with a torch having a good many different tubes leading to the head so that almost any combination of gases at varied pressures might be obtained. Mr. Napolitan evolved from these experiments interesting theories pertaining to the reactions which take place in cutting, together with their relation to success in cutting cast iron. He has noted these theories in a separate paper. We are presenting these thories to the members of the society for what they are worth. We can actually cut cast iron and we do it by *preheating the oxygen.*

In the paper prepared by Mr. Napolitan, he said:

From the ease with which wrought iron is cut we may conclude that an aggregate of ferrite combines with oxygen with greatest avidity, and permits the propagation of a cut with least interruption. As the carbon content is increased, there is a material change in the nature of the metal. In place of the preponderance of ferrite grains, we recognize the formation of cementite, and its union with some of the ferrite to form pearlite—the original mass of pro-eutectoid ferrite rapidly diminishing in prominence. As we should anticipate from the nature of pearlite, no material change is noticed in the performance of these alloys under the cutting torch. Of course, an ultra-precise consumption test would probably indicate a lowering of the efficiency coefficient, but from all appearances no unusual difficulty is experienced in cutting carbon steels up to about 80 to 90 point carbon. But here, a definite transition is indicated by a distinct laboring of the cutting torch. While the torch will begin to cut with practically the same effort, and proceeds to completion without interruption of unusual delay, yet the kerf is wide and ragged and undeniably distinguishable from that of a mild steel cut. It is recognized practice, now, to preheat the piece to be cut to a black or dull red heat, when the impediment, whatever it was, seems to have been entirely eliminated.

But let metallography explain the sudden change of properties of the steel. As the carbon content of the hyper-eutectic steel was increased, the proximate mass of pearlite increased, and the pro-eutectoid ferrite correspondingly diminished in volume, until eventually a point was reached where all of the cementite and ferrite existed in the stratified or laminated relationship of pearlite. This state is recognized as existing where the carbon content is between 80 and 90 points —the approximate analysis of pearlite is yet undefined. As the carbon content is further increased, there appears a constituent that we know as pro-eutectoid cementite—in fancy, the cementite which has been ejected from the pearlite growth. It is circumstantial that the presence of this pro-eutectoid cementite is directly responsible for the increasing difficulty of our cutting. But why did preheating of the steel before cutting make such a remarkable difference in the results? To be sure, the rise in temperature might affect the stability of any martensite, troostite, or even sorbite that might have existed, but the temperature was too far removed from the Ac_{321} point to affect the characteristics of the pearlite. And surely the pro-eutectoid cementite was unchanged —and it was this same constituent that we blamed for the difficulty.

Again, as the carbon content is substantially increased, an equivalent interference with cutting is apparent, until, when the carbon content approaches 2.5 per cent, cutting becomes so labored as practically to cease, and no amount of preheating short of incipient fusion will permit it to propagate. As you are aware, the metal is now termed "cast iron," and a micro-analysis indicates that in addition to the presence of a certain amount of pearlite and pro-eutectoid cementite, as well as certain foreign and, to our discussion, unobtrusive substances, we recognize the presence of the final and most stable state of carbon-graphite. The pearlite constituent exercises a favorable influence upon the operation of cutting—and the pro-eutectoid cementite, while it impedes cutting, is readily compensated by a slight preheating—but the graphite presents an entirely new problem.

We might digress from the subject enough to present some remarks that would prove the fallacy of at least one of the stereotyped explanations of why cast iron cannot be cut—that the melting point of the slag is appreciably higher than the melting point of cast iron.

A micro-analysis of the structure of an average cast iron—and by average we refer to a gray cast iron of about three to four per cent carbon—would indicate a structure identical with that of a hypothetical steel of the same carbon content, except that some of the carbon seems to have been precipitated as graphite. But should that identical pour of cast iron have been cast against a cold iron mold, or otherwise chilled, the carbon would not have been precipitated as graphite and we should have had what we shall call a "chilled cast iron," or a "white cast iron,"—and it would actually have been a hyper-eutectic steel. Such alloys are not uncommon in commerce, and the fact that operators have been able to cut them with no extraordinary effort has been responsible for innumerable false claims that cast iron has been cut. Unfortunately, the nomenclature of steels and irons is not clearly defined, and undoubtedly a chilled cast iron is but an extension of the hyper-eutectic series. The melting point of an iron-carbon alloy is a constant of its composition, whether, in the solid state, the metal exists as a typical cast iron or as a steel. Long before the point of fusion, the carbon and the iron exist in one relationship, that of austenite. The conditions affecting the pouring of a melt of cast iron would determine the final state of its constituents— and we might as readily produce a gray cast iron or a chilled white cast iron—the carbon as graphite or the carbon as in cementite. In either event, the melting points of the resulting products would be identical. We agree that chilled cast iron can be cut with comparative ease. It is evident, then, that the melting point of slag is not responsible for the difficulty encountered in cutting cast iron.

We had concluded that while the existence of pro-eutectoid cementite appreciably retarded cutting, the presence of but a comparatively small amount of graphite completely prevented cutting. The phenomenon, if it were true, is unique, for it would pre-suppose the incombustibility of carbon. Science contradicts us immediately. In fact, our own welding practice belies us. We might point to the reaction accompanying the removal of carbon from automotive cylinders by the oxygen method—or, leaving our immediate field, we might mention the explosive combustion of carbon in ordinary gun-powder. We are forced to conclude then that, far from retarding the combustion of the steel matrix, the graphite of cast iron should actually assist it.

We investigated further to determine how much graphite influenced cutting. We obtained specimens of so-called malleable castings of the characteristic "black heart" structure. Such a structure is made in this country by the annealing of white cast iron in which all of the carbon exists in cementite or pearlite, the latter in some cases entirely removed. The treatment decomposes the cementite to precipitate the carbon in minute particles, differing from the graphite of gray cast iron in their extreme subdivision and uniform distribution throughout a ferrite matrix. In making a black heart casting, an oxidizing packing is used in this country so that while the core is that of a black heart casting, the mass near the surface is ferrite. We removed this shell of ferrite so that our materials indicated, under the microscope, a uniform aggregate of ferrite and temper carbon. By preheating this piece to a dull red heat, it was cut with the characteristics of a high-carbon steel. Then we were satisfied that carbon as such did not prevent cutting, but that the physical state of that carbon was responsible. As plates of graphite, cutting was prevented; but as finely divided particles, cutting was scarcely impeded.

Reconsidering our previous observations in the light of this development, we began to substantiate our first logical hypothesis. We found, to summarize, that ferrite permitted most readily to be cut. Pearlite with pro-eutectoid ferrite did not materially affect the conditions. A completely eutectic composition first suggested a transitory stage. The existence of pro-eutectoid cementite retarding cutting; but preheating of the piece to a red heat readjusted the conditions so that cutting was again as efficient as in the case of ferrite. As the comparatively low temperature produced by preheating was insufficient to effect any change in the physical state of the constituents of the alloy, we were forced to conclude that the addition of heat units affected a definite constant, which we assumed was the heat of combustion of the iron, as the two forces were of like characteristics. Then a constant result from a variable made axiomatic the existence of a second variable. Our second variable then, we concluded, was the cooling effect of the stream of cutting oxygen, and a further thought suggested a third variable in the time of chemical reaction between the iron and oxygen. The preheating flames ignited the steel—the cutting oxygen produced combustion—and the propagation of the cut was a natural consequence. But as the carbon content was increased, the speed of the reaction was materially lowered; however, the velocity of cutting oxygen to insure a continuity of oxygen and slag to the bottom of the cut, was a constant. Then, eventually, a point was reached where the rate of combustion between the iron and oxygen was so slow that the heat units liberated from the reaction were dissipated to such an extent as no longer to ignite adjacent masses of metal—and cutting ceased. By preheating the piece before cutting, we add to the forces on the weakening side of the equilibrium, and cutting once more obtained. The heat units so obtained compensated for the relatively less heat units liberated from the chemical combination of the iron and oxygen in a definite unit of time.

While the pearlite and pro-eutectoid cementite are readily compensated, the graphite carbon effectively prevents cutting by the ordinary means. No addition of heat units short of incipient fusion, by preheating the object, restores the equilibrium. We cannot strengthen further one side of our equilibrium, but we have not attempted to affect the other side. We had made no attempt to reduce the cooling effect of the cutting oxygen. We therefore experimented in this direction, and found that we could so effectively preheat the cutting oxygen that we could restore the equilibrium without preheating the object.

In regard to the foregoing it will be of interest to the reader to know that the following article was published in the July, 1919, issue of *Autogenous Welding:*

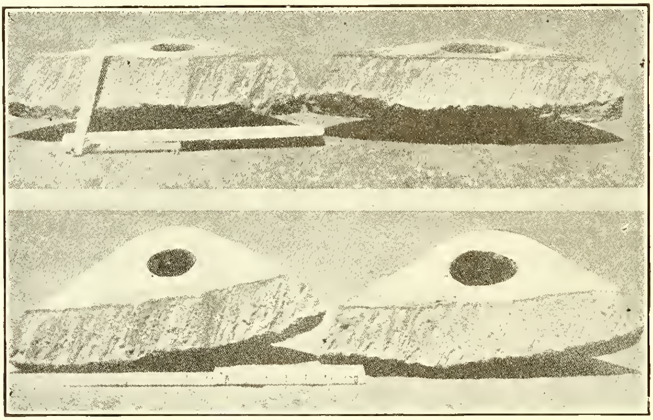


Fig. 227.—Four Corners of Large Cast-Iron Stone Crusher Head Beveled with Cutting Torch for Welding.

"Substantial progress has been made which shows that cast iron cutting with the torch is a practical commercial proposition. Proof is shown in the two views of the four corners of a large stone crusher head that were prepared for welding by beveling the edges with the torch as shown in Fig. 227. The job was accepted in our welding shop, with a promise of completion in two days, but it was found that a much longer time would be required alone to bevel the edges by chipping. The staff of the Engineering and Research Department of the Davis-

Bournonville Co., which had been experimenting in cast iron, was appealed to, with the result that the four pieces were made ready for welding in less than one hour!

"Each corner piece represents a cut $4\frac{1}{2}$ in. thick and 17 in. long, with an area of 76 sq.in. The cuts were made in $6\frac{1}{2}$ min. each, using 24 cu.ft. of oxygen and about 4 cu.ft. of acetylene. The cut surface produced was smooth and the edges were sharply defined, as is shown in the views. The kerf was about $^5/_{16}$-in. wide at the top and bottom—about the same as would be produced by cutting steel of the same thickness. The

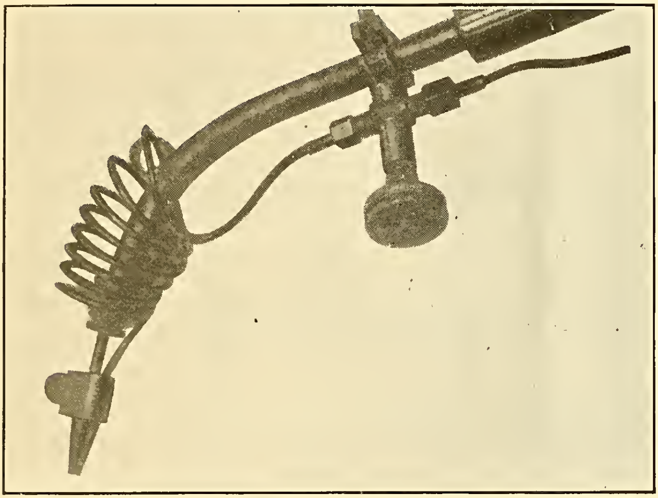


FIG. 228—Cutting Torch Made to Preheat the Oxygen Cutting Jet.

process was not one of melting, as the sharp edges prove—in fact the finish of the cut surfaces compares favorably with that of steel. After the cuts were started they were carried through to completion without a stop, and the pieces dropped apart of their own weight."

Since it is known that the cutting of cast iron is principally accomplished by preheating the oxygen, attention is called to the fact that there have been cutting torches on the foreign market for several years so made as to preheat the oxygen cutting jet. One of these is shown in Fig. 228, the principle on which it is made being self-evident.

Another torch which is a combination carbon electrode and oxygen jet is shown in Fig. 229. This was patented by R. E. Chapman and J. W. Kirk in 1918. The construction is obvious as the electric current source and connections are shown at the left and the oxygen tank and tubing at the right. The carbon electrode has a hole in the center through which the oxygen jet is projected. As the temperature of the arc is considerably

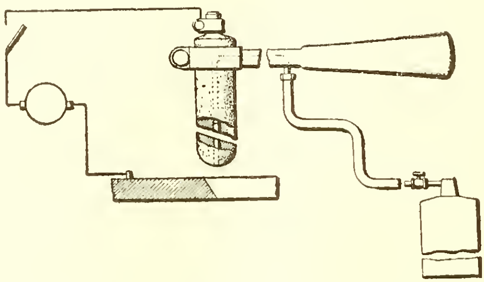


Fig. 229.—Carbon Electrode and Oxygen Jet Torch.

higher than that of the gas torch the oxygen is highly heated as well as the metal.

OXY-HYDROGEN CUTTING

Elmer H. Smith, secretary of the Commercial Gas Co., writing in the *Welding Engineer* says:

As I had never had the opportunity to get an accurate cost on oxy-hydrogen cutting, either through experience of others or through my own work I was very glad to take the data on a recent job where I could get absolute facts and figures.

The work consisted in splitting a number of steel plates 13/16-in. thick by 26 ft. 10 in. long and was done by one of our spring motor cutting torch carriers with our standard straight line torches with a No. 1 cutting tip made especially for hydrogen cutting.

As cutting is a process of burning we convert the iron to iron oxide or Fe_3O_4, which means that the burned iron is composed of three parts of iron and four parts of oxygen. Since the atomic weight of one part of iron is 56 as compared to 16 for oxygen, this means that the weight of the oxide would be composed of 3×56 unit weights of iron and 4×16 unit weights of oxygen, or a ratio by weight of 168 parts of iron to 64 parts of oxygen. In other words, if we were to take 232 lbs. of slag produced by cutting it would contain 64 lbs. or about 700 cu.ft. of oxygen and 168 lbs. of iron.

For means of comparison the following figures are set forth, showing what the gas consumption would be on this particular class of work if the cutting was done with theoretical efficiency.

Fe_3O_4 = Fe 168, O 64 (pts. by weight).

26 ft. 10 in. = 322 in.

322 in. — 13/16-in. thick = 261.6 sq.in. of cut.

4 cuts = 1046.4 sq.in.

1046.4 sq.in. of cut 3/32 in. thick = 98.1 cu.in. metal removed.

Steel weighs .2831 lb. per cu.in.

98.1 cu.in. weighs 27.8 lbs.

Now if all the oxygen used had combined with the iron to do the cutting we would require 64/168 of 27.88 lbs. or approx. 10.6 lbs. of oxygen. As 1 lb. oxygen equals 11.209 cu. ft., the amount required theoretically is 118.81 cu.ft. In actual practice, however, we cannot obtain any such efficiency, as the cutting jet must be of sufficient volume and pressure to blow out the slag and clean the kerf of oxide. This means that an excess of oxygen must be used to do the more or less mechanical part of the work. In addition some oxygen must be supplied to combine with the hydrogen to provide the heating jet. None of this oxygen is used in converting the iron to Fe_3O_4 and represents a total loss as far as the theoretical figures go.

Of course if we expected to get down to exact figures we should have an analysis of the steel to be cut and allow for the oxygen necessary to convert the carbon and manganese to oxides, but the proportion is so small as to be almost negligible.

Now let us see what obtains in actual practice in machine cutting of ordinary steel ship plates free from rust but coated with the usual amount of thin mill scale.

I set up the motor and after a short trial adjusted the oxygen pressure to 22 lbs. pressure and the hydrogen to 3 lbs. This oxygen pressure may appear a trifle high, but it must be remembered that it was not only efficiency in gas that was desired but also saving in time and there was too the friction of a 25-ft. length of hose to overcome. (I have often cut 1-in. steel with less than 10 lbs. pressure.) I then adjusted the speed of the machine to 14 in. per minute which was the maximum speed at which the cut would clear itself perfectly. The pressure gages, previously tested for accuracy, showed 1780 lbs. on the oxygen and 1800 lbs. on the hydrogen drum. At the end of the run the gages showed 305 lbs. on the oxygen and 1175 lbs. on the hydrogen. As the drums were 200 cu.ft. capacity the consumption was 1475/9 = 164 cu.ft. oxygen and 525/9 = 70 cu.ft. of hydrogen. As the oxygen for the heating jet was supplied from the same drum and through the same regulator as the oxygen for the cutting jet it was impossible to determine the amount used in the heating jet, but I would estimate that it was approximately 30 cu.ft. as it was much more than is used in any oxy-hydrogen welding flame. This would leave 134 ft. oxygen for the actual cutting operation, which is but 15.19 cu.ft. more than the theoretical amount required. The kerf was just a few thousandths of an inch under 3/32 in. which would throw the balance against the efficiency slightly, but computing from the above figures it is shown that the actual results are 88 per cent of the theoretical figures. On account of the lack of definite figures on cost of cutting with either the oxy-acetylene or oxy-hydrogen process on actual cutting jobs it might not be amiss to compute the foregoing figures to show the approximate cost per sq.in. of cut.

Purity of oxygen 99.5.
Purity of hydrogen 99.8.
1288 lineal inches 13/16 in. thick = 1046.4 sq.in.
164 cu.ft. oxygen @ 1½c..... $2.46
70 cu.ft. hydrogen @ 1c.... .70

Total gas cost 3.17
Total oxygen cost per sq.in. cut..... $.00235
Total hydrogen cost per sq.in. cut.... .0007

Total gas cost per sq.in. cut......... $.00305
Oxygen per lineal ft.... 1.53 cu.ft.
Hydrogen per lineal ft.. .65 cu.ft.
Total gas cost per lineal ft. cut..... $.02945

These figures cannot be obtained in free-hand cutting and could not be expected as the cutting jet must be maintained at a considerably higher pressure to overcome the unsteadiness on the part of the operator. The heating flame must also be larger in free-hand cutting, or the cut will frequently be lost requiring the operator to turn off the cutting jet and start over.

From the figures given me on the use of oxy-acetylene cutting in which the oxygen was approximately 98 per cent pure, the cost of the cut per lineal ft. was 6c. However, I did not conduct the test with oxy-acetylene and am taking the results obtained by the foreman in charge. He stated that the pressure in the oxygen was 35 lbs. and on the acetylene 8 lbs. The resulting cut was not nearly so smooth nor regular as that produced by the oxy-hydrogen and in addition there was an accumulation of slag at the bottom of the cut which was entirely absent when hydrogen was used.

We all know that if oxygen is diluted with a very small quantity of incombustible gas, such as carbon dioxide, its efficiency is greatly reduced and a decrease of 4 per cent in purity results in an increased consumption of 60 per cent in oxygen. But we may start out with a very pure oxygen in oxy-acetylene cutting and still have a high consumption, which would lead one to believe that the oxygen of the cutting jet is diluted after it leaves the cutting tip with the products of combustion of the heating flame, which contains carbon monoxide, which is not present in the oxy-hydrogen flame.

It was interesting to note that when the heating jet was adjusted to heat at about the same rate as oxy-acetylene in starting the cut the top of the kerf was very slightly melted over making a rounded edge, but that when the flame was so adjusted that it required a half a minute or more to start the cut the top edges of the kerf were sharp and square as they were at the bottom. Although with the flame adjusted at a point requiring 30 seconds to start the cut, after it was once started no trouble was experienced by losing the cut and in every case the full 26 ft. 10 in. was cut without an interruption, except on the extreme end of one piece which had a thick scale of rust.

Although it is seen that in this particular case the consumption of hydrogen is considerably less than half the amount of oxygen, my experience has not been quite so satisfactory in cutting scrap iron, that is scrap boilers, etc., where there is more or less rust and boiler scale to contend with and also the frequent interruption of the cutting operation in shifting from one piece to the next. In cases of this kind the heating flame must be of ample capacity to penetrate the scale and to start the cut almost immediately. It is also the custom to have the torch burn while moving about from one cut to the next. This increases the hydrogen consumption about 100 per cent more or less depending on the operator. The thickness of the metal to be cut also determines the proportion of hydrogen used. It is probably safe to say that the amount of both gases used will be practically doubled.

If it would not complicate construction to the point of impracticability it would be a step in the right direction to make a cutting torch with a valve control that would open first the valve controlling the combustible gas, then the oxygen for heating jet and lastly the cutting jet valve.

CHAPTER XVI

CUTTING MACHINES

Where close cutting to a line or pattern with a gas torch is desired, some mechanical device must be provided for guiding the torch. A properly constructed machine saves time, material and gas.

The more common mechanical devices in use are for feeding

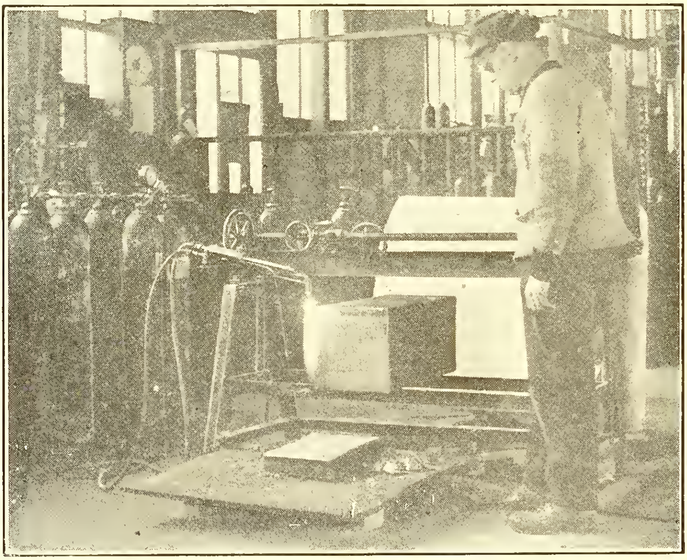


FIG. 230.—Cutting a Billet with an Oxweld Machine.

the torch in a straight line. These are used to cut bars, billets, boiler plate, armor plate and the like. An Oxweld straight-line cutting machine is shown in Fig. 230. An ordinary cutting torch is used in this case, and the end of a 12 × 12-in. billet has just been cut off. The feed screw may be turned from either end by means of handwheels, and means are provided for cross adjustment.

Another device, made by the Davis-Bournonville Co., is shown in Fig. 231. The pieces, which were cut the long way, measured $15 \times 13\frac{1}{2}$ in. This machine has a handwheel on one end of the feed screw and a cone pulley, for power drive, on the other. Unlike the device first shown this one is not mounted on legs but has a short section of I-beam for a base. On this account

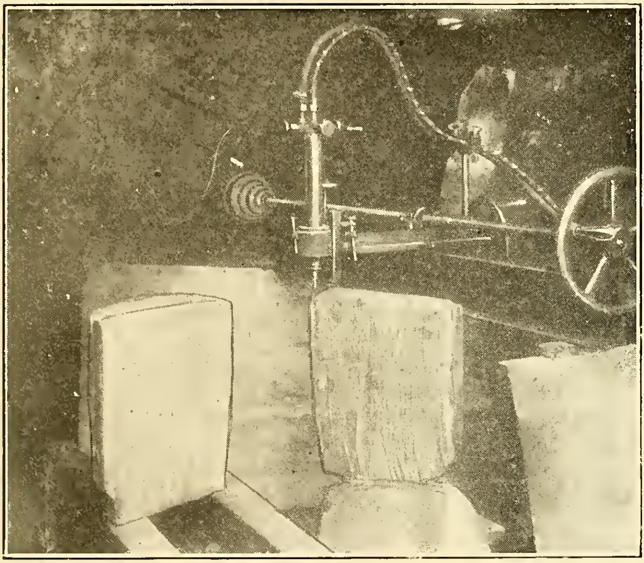


FIG. 231.—Another Straight-Line Cutting Machine.

it may be placed on the object to be cut or laid on blocks or horses, as occasion demands.

The device shown in Fig. 232 differs from either of the foregoing in that racks are used in place of lead screws. This is made by the Great Western Cutting and Welding Co., San Francisco, Cal. The heavy structural iron base is so made that it may be placed on the work, laid on blocks or horses or mounted on legs. Means are provided for adjusting the torch up or down or at an angle.

Any of these machines may be used for cutting out marked square, rectangular, round or irregular shaped holes. Where the metal is thick, it is often better, especially on repetition work, to drill a hole through for starting.

The Radiagraph.—The Radiagraph shown in Fig. 233 is made by the Davis-Bournonville Co. It is a motor-driven device, with oxy-acetylene or oxy-hydrogen cutting torch, adapted to cutting along straight lines or circles in steel plate from $\frac{1}{4}$ in. to 18 or 20 in. in thickness, the speeds varying from 2 in. to 18 in. per minute, according to the thickness of the plate. For

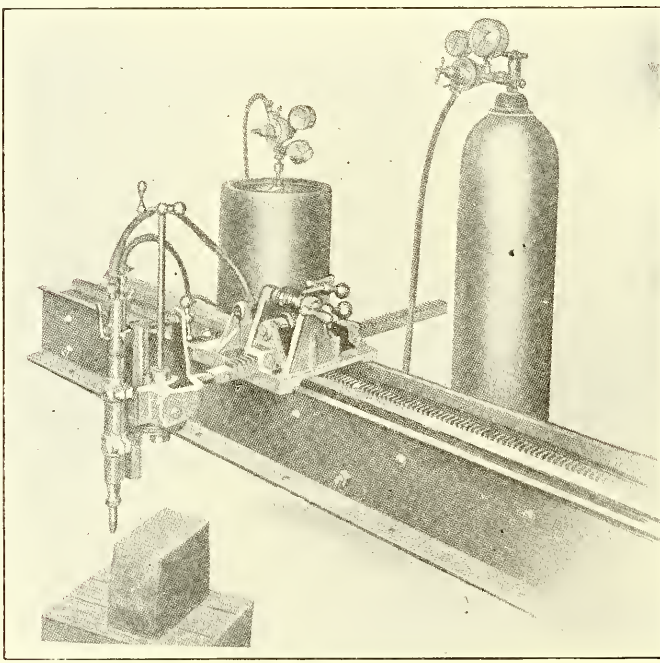


FIG. 232.—Portable Cutting Machine with Rack Feeds

straight line cutting, it operates upon a parallel track, and for circle cutting, with a rod and adjustable center. The device consists principally of a three-wheeled carriage driven by an electric motor attached to the carriage, which may be connected to the ordinary lighting or power circuit, either d.c. or a.c., 110- or 220-volt circuit. An adjustable arm and torch holder provides for raising or lowering the torch while in operation, and for adjustment at an angle for bevel cutting. The adjustable arm also permits of following an irregular line within a

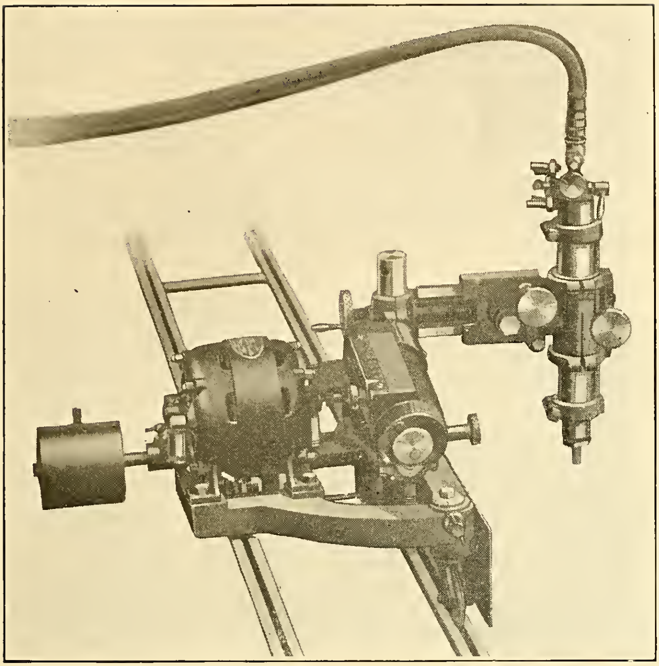


Fig. 233.—Davis-Bournonville Radiagraph.

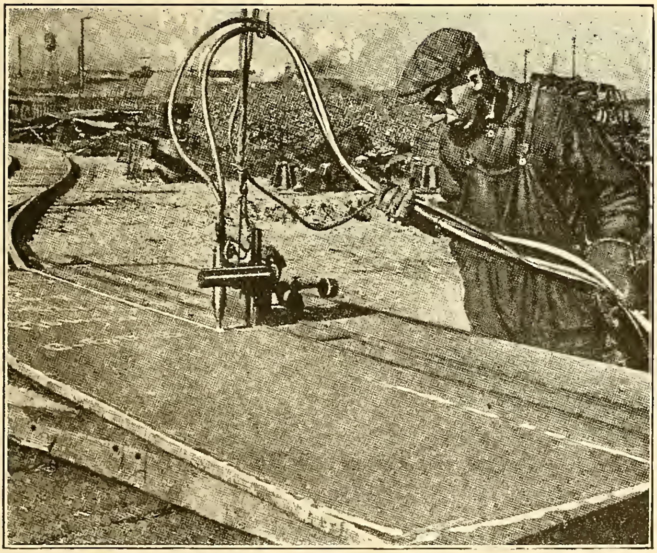


Fig. 234.—Radiagraph Cutting Steel Plate at the New York Shipbuilding Yards.

variation of 3 in. on either side of a straight line. The cutting torch is connected by hose to the gas supply. The machine is portable, weighing approximately 50 lb. complete, and has proven an invaluable aid in steel cutting, greatly facilitating such work in shipyards and steel mills, several machines being employed advantageously in some of the larger plants.

An example of some of the straight line cutting done by the Radiagraph is shown in Fig. 234. Here the track has been

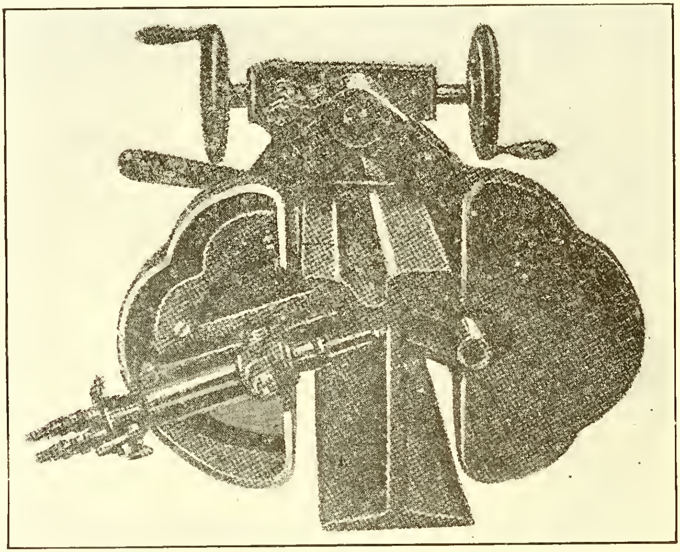


Fig. 235.—Davis-Bournonville Railograph.

laid on a heavy piece of ship plate and the torch is fed along at a uniform rate by the motor.

The Railograph.—For cutting railway rails the device shown in Fig. 235 is used. This is clamped to the rail while it is in position on the roadbead if desired. The cutting torch may be mounted in a holder on either side of the rail. Each holder is carried by a slide. Attached to each holder is a roller which runs in contact with a cam formed in such a way that it provides for maintaining the tip of the cutting torch at a uniform distance of about $\frac{1}{8}$ in. from the surface of the work as the torch is fed around the rail. Feeding of the torches is accomplished by two handwheels which transmit motion through a set of suitable gearing. In operation the torch is first applied at one side of the rail and fed over the line on which the cut is to be made, one-half of the base and head of the rail and the web being cut in this way. The torch is next removed from the holder and mounted at the opposite side of the rail, where it is again passed over the line of cut, with the result that the remaining half of the base and head of the rail is severed. A 9-in. traction rail can be cut off in about three minutes.

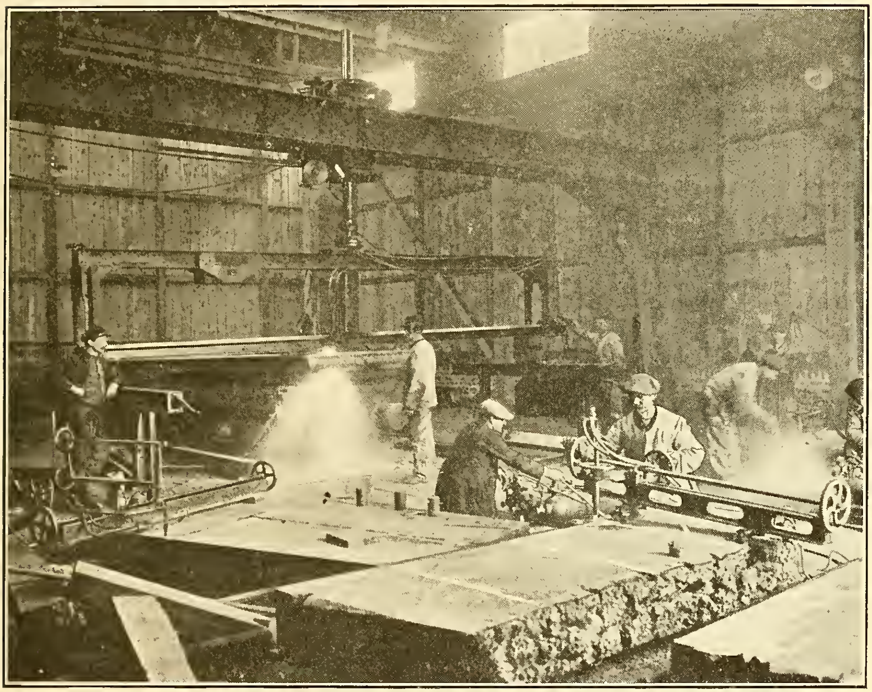


Fig. 236.—Cutting Heavy Plate at the Schneider Works, Creusot, France.

The cutting of heavy steel plate in the great Schneider Works, Creusot, France, is shown in Fig. 236. The portable devices are very similar to those used in the United States. In the background is a huge machine so made that it can be used to trim ends, square up a plate and cut angles or circles. The torch carriage is fed along by a lead screw run by a motor seen at the extreme right. A motor-operated device will raise or lower the frame or give it a circular movement. The plates to be cut are run into position on small flat cars.

Circular Cutting.—The Radiagraph cutting circles, is shown in Fig. 237. The work was $2\frac{1}{2}$ in. thick and was cut at the rate of 6 in. per minute. Note the true circle and surface of the cut. The pieces were for a special type of heater for the Government. The round piece, or flue sheet, is 30 in. in diameter and the ring, or flange, 45 in. outside diameter.

Another device is the Holograph, shown in Fig. 238. It

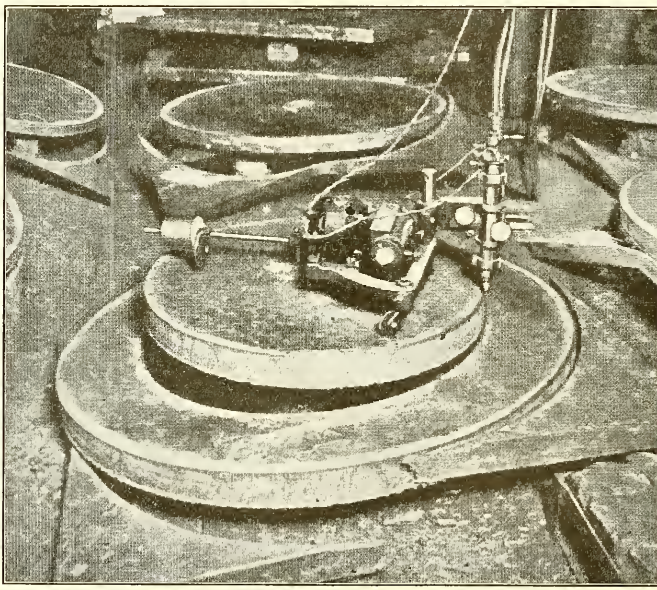


FIG. 237.—Radiograph Used for Circular Work.

is a device for cutting holes in the web of a rail, or in structural iron, of not more than $\frac{3}{4}$ in. thick. It is quickly attached and accurately adjusted. It pierces through the iron almost instantly, without any previous drilling, and will cut smooth round holes from 1 to 2 in. in diameter in from 30 to 60 sec. It is particularly adapted for railroad work, and enlarging or cutting holes in building and bridge work.

The Magnetograph.—The Magnetograph shown in Fig. 239 was designed for mechanically cutting circles up to 12 in. diameter in steel plate in perpendicular position, such as cutting port holes in the side plates of ships. Steel plate from $\frac{1}{4}$ in. up to several inches thick is cut quickly, with a finished

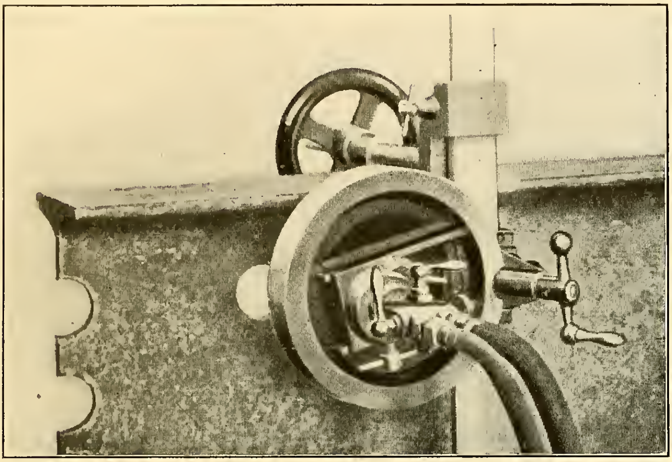


FIG. 238.—Davis-Bournonville Holograph.

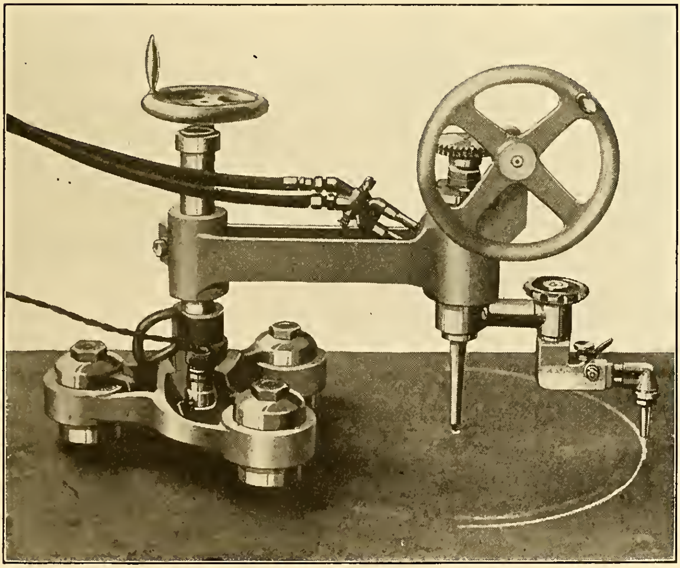


FIG. 239.—Davis-Bournonville Magnetograph.

and true surface, the movement of the oxy-acetylene or oxy-hydrogen torch and flame being given by handwheel and gears.

Cutting is accomplished at varying speeds according to thickness of plate, from 3 in. up to 20 in. per minute, or even faster on light plate. The device is constructed as much as practical of aluminum to obtain lightness, and is held firmly on the plate by means of three electromagnets, connected by wire to an electric circuit (direct current) or to battery.

The Camograph.—The Camograph, Fig. 240, is an adaptation of the Holograph. It is of the same general construction, except that it is larger and has a wider range of work. It is fitted with a cam for each particular kind of work, and

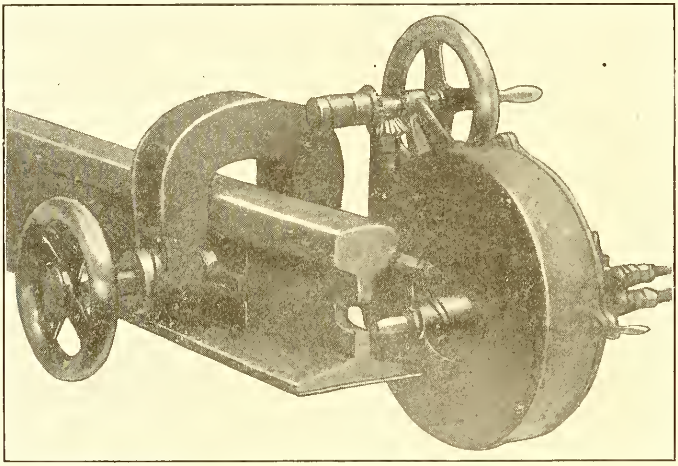


Fig. 240.—The Camograph.

will cut almost any form desired, within the capacity of the machine. This machine requires special cams for each operation.

The Camograph No. 2, shown in Fig. 241, is a later development of the Davis-Bournonville Co. It is automatic in operation and is used for cutting openings in steel plates that cannot be done conveniently or economically on a drilling machine. The torch is mechanically traversed over a fixed path and at a predetermined speed. The path followed is controlled by an internal cam at the top of the machine, the shape of which determines the shape of the opening being made, the double-jointed radial arm permitting universal movement of the flame which perforates the steel. The principle of the cam guiding action is unique. The feed roller is magnetized by a powerful electromagnet, and is thus attracted to the inner face of the cam, the parts in contact being made poles of the magnet, one of which rotates and thus acts as a traction driver. The roller is driven by a small variable-speed motor through double worm

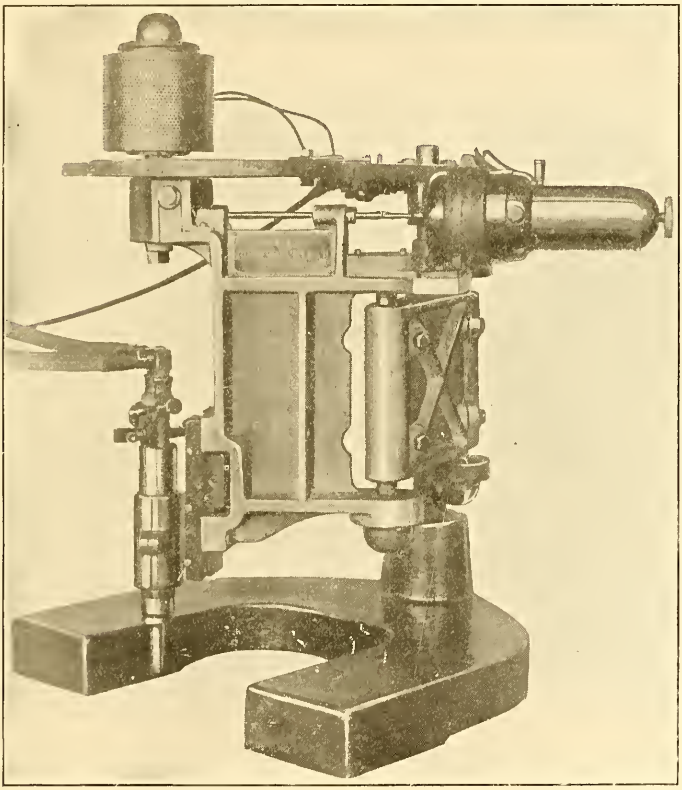


Fig. 241.—Camograph No. 2.

gearing, the magnetic attraction being sufficient to cause it to travel along the face of the cam in a positive manner. Direct current is required owing to the magnetic feature, and the control consists of a double push-button switch for starting, stopping and also for energizing the magnet. Arrangement is provided whereby when the cutting oxygen is turned on the feed motion automatically starts. The nominal diameter of the largest hole cut is 7 in., but openings other than circular, having one dimension much larger, may be provided for. All thicknesses of plate used on the largest marine boilers are readily cut with this machine. The machine is 17 in. wide, 15 in. deep, 25 in. high, weighs 125 lb., and uses 110 volt, direct current.

The Great Western Cutter.—The machine shown in Fig. 242 is made by the Great Western Cutting and Welding Co.

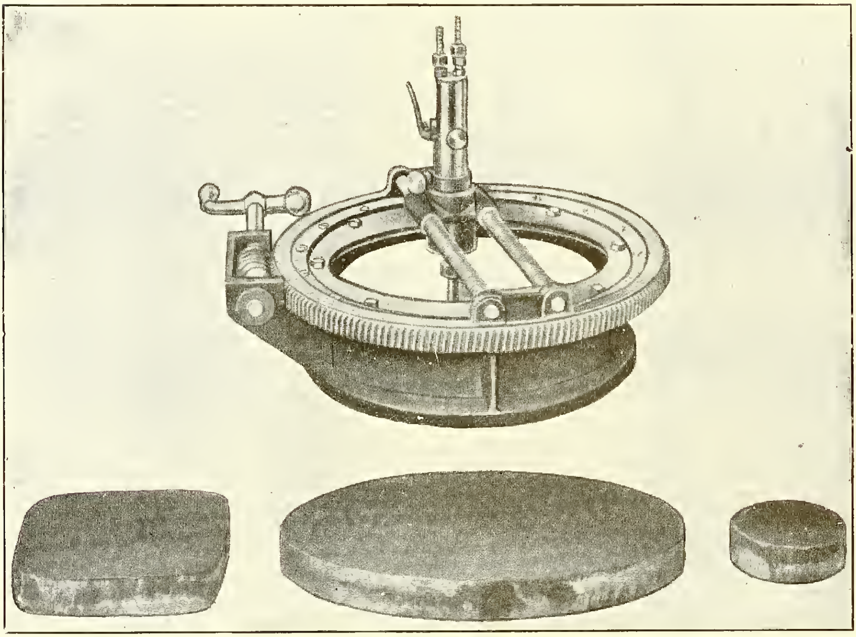


Fig. 242.—Great Western Cutter.

It is designed to cut round, square or oval holes. Three master plates are furnished for holes of these shapes. By turning the handle the torch travels around the inside of the form, to which it is held by the two coiled springs shown. The machine is simple and light. Extensions are furnished for cutting large holes. For odd-shaped holes extra plates are required. This machine is especially adapted for boiler shops, shipyards, etc., in cutting hand holes, manholes, fire-box door holes, and holes in tube sheets.

The machine shown in Fig. 243 is known as the Pyrograph and is made by the Davis-Bournonville Co. The model shown is not the latest, but well illustrates the general principles of the more improved ones. It was designed primarily for boiler-shop use in turning flanged boiler heads or cutting openings for doors, manholes and the like. In one shipyard boiler plant, flanged combustion chamber heads, $\frac{3}{4}$ in. thick with a flange periphery of 27 ft., were trimmed and beveled to the calking angle in 30 min., exclusive of the setting up.

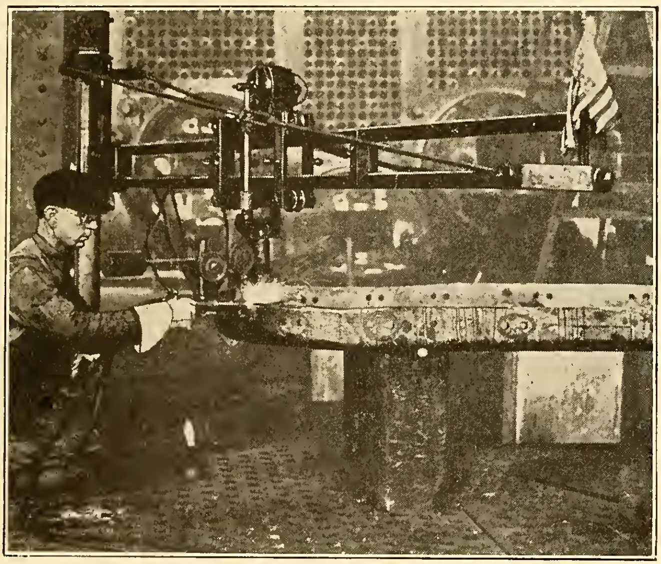


FIG. 243.—Pyrograph Trimming and Beveling Boiler Flanges.

As can be seen, the Pyrograph comprises a motor-driven carriage supported on a radial arm of a length that provides for cutting the flange of a 9-ft. diameter boiler head at one setting. While the largest diameter circle that can be cut at one setting is 9 ft., much larger work may be trimmed and beveled, inasmuch as the arm can be swung through a semi-circle of 20 ft. or a full circle of 20 ft. diameter, provided the shop conditions permit the arm to swing in a complete circle. Heads larger than 9 ft. diameter are reset as many times as may be found necessary to reach the flange all around.

The radial arm construction is light but rigid, consisting of two cold-rolled parallel round steel bars firmly tied together by end connections and intermediate spacer blocks, and supported by a truss rod. The vertical cast-iron pivot member of the radial arm is mounted on ball bearings at the top and bottom, in order to insure the maximum ease of movement. The steel post around which the radial arm swings is adjustable vertically by means of a crank operating a rack-and-pinion gear. A dog and rachet hold the post at any height within the limits of adjustment required.

The column has a broad flanged base which may be bolted

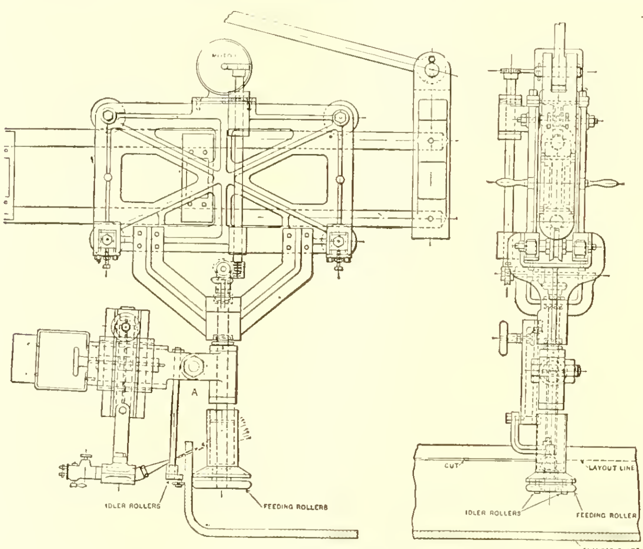


FIG. 244.—Details of Pyrograph Feed Mechanism.

to a cast-iron floor plate or a concrete foundation if required to be self-supporting, or the top of the post may be shackled to a column of the shop building and the base supported on an ordinary floor without an individual foundation.

The carriage is supported on the radial arm by four grooved ball bearing rollers which provide for the easy radial movement required to follow the feed action freely. The carriage and the arm derive their movements from the feeding mechanism which operates directly on the part to be beveled, the flange part itself acting as the track and guide for the feeding mechanism, as shown in Fig. 244.

The torch is adjustably mounted on the carriage beneath the radial arm, and the tip may be directed at any angle required to cut to the desired calking angle.

The flange to be trimmed and beveled is gripped between the three feeding rollers, two of which are small idlers on the side next to the torch while the driving roller, considerably larger, is located on the far side of the flange. The driving feed roller derives its motion from a small electric motor mounted on top of the carriage and driving through a reducing train of worm and bevel gears. Variations of speed are provided by making the upper worm and worm gear replaceable with worm gears of different ratios. The following speeds are available: 12 in. in 70 sec., 12 in. in 90 sec. and 11 in. in 60 sec.

The pressure on the feed rollers required to produce the traction necessary to traverse the torch and carriage is obtained from the weight of the torch, the slide rests on which it is carried and the frame to which the two idler feed rollers are attached. The frame carrying the slide rests and idler feed rollers is pivoted, and the weight forces the idler feed rollers against the side opposite the driving roller with sufficient pressure to traverse the carriage positively. The feed mechanism operates on any shape whether straight or curved, thick or thin. Flanged sheets are generally rough, presenting a more or less irregular contour, but this does not interfere with the carriage traverse and the torch action. The operator may interrupt the feed at any point by raising the frame, thus relieving the pressure on the feed roller.

The driving roller and its shaft are protected by a shield of fireproof composition having a beveled flange at the bottom, on which the sparks and slag have no effect. The machine, once set, trims a flanged sheet evenly all around, provided the sheet has been properly leveled. Otherwise it is necessary to chalk a line to be followed.

In the plant of the New York Shipbuilding Corporation, three different combustible gases are used in cutting torches, namely, carbo-hydrogen, acetylene, and hydrogen. The combustible gas selected for different classes of work depends upon the thickness of the plates which have to be cut. The range of thickness handled by the different gases is as follows: Up to 3 in., carbo-hydrogen; 3 in. to 6 in., acetylene; and over 6 in., hydrogen. It will, of course, be understood that either of these gases is mixed with oxygen.

A Universal Cutter.—A machine built somewhat along the lines of the Pyrograph, but a much more universal machine, has been developed for use in the shops of the General Electric Co., Schenectady, N. Y. This machine is shown in Fig. 245. It can be set for automatically making circular, spiral, radial or tangential cuts. Its rate of feed can be varied from 1 to 72 in. per minute, according to the character and thickness of the metal. The base of the machine is provided with a

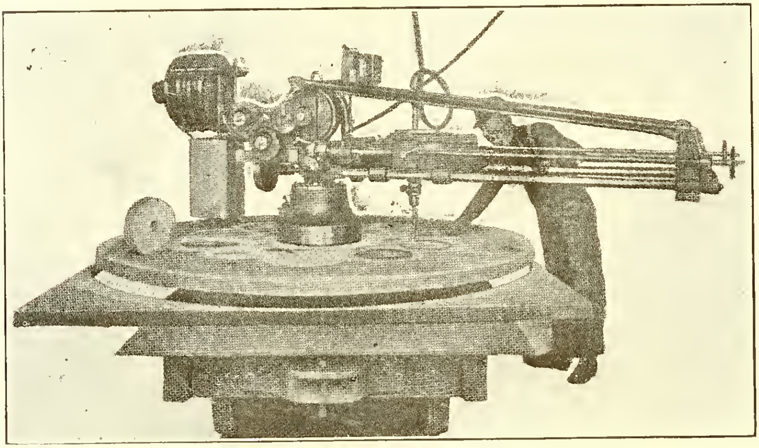


FIG. 245.—Automatic Universal Cutting Machine.

powerful electro-magnet to be used if the machine is placed on a rough or uneven surface and also to hold it in position when it is necessary to perform cutting operations on work held in a vertical plane. Ordinarily, the weight of the machine is sufficient to hold it steady. As shown, the machine is mounted on a truck for easy transportation, as it weighs 1,900 lb.

The Oxygraph.—With the Oxygraph, steel plate from 1 in. to 15 in. or more in thickness is cleanly cut with a narrow, smooth kerf, along straight lines, sharp angles, or curves, according to drawing or pattern. The pantagraph principle is employed, with a motor-propelled tracing wheel, with which the lines of the drawing are followed and reproduced with the cutting torch. Either the oxy-acetylene or the oxy-hydrogen cutting flame is used, with hose connection to the source of gas supply. The only power required is for revolving

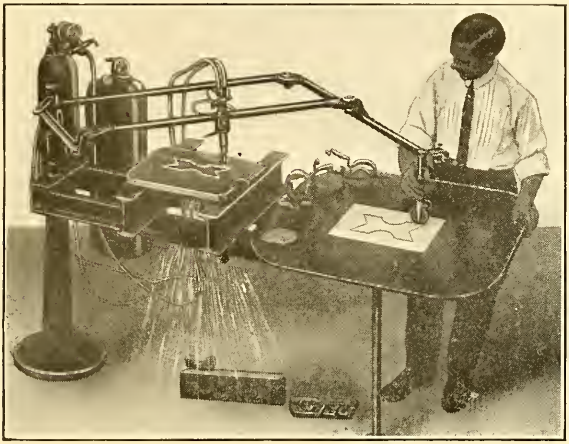


FIG. 246.—Single-Torch Oxygraph.

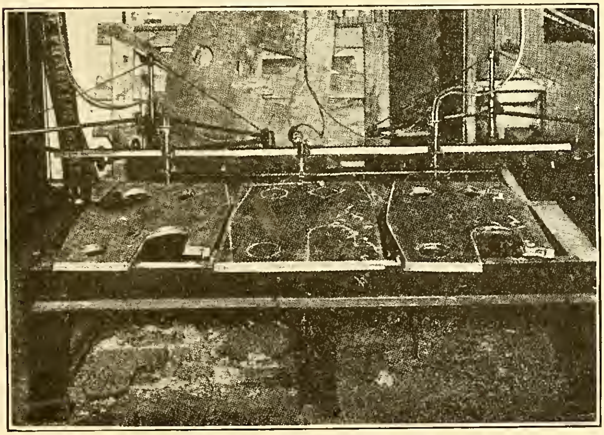


FIG. 247.—Oxygraph with Two Torches.

the tracing wheel, and this is supplied by a small motor attached to the tracing head, which may be connected to the ordinary electric light or power circuit. A universal motor, either d.c. or a.c., 110- or 220-volt circuit, with rheostat and friction governor is used. The speed of cutting varies from 2 to 18 in. per minute, according to the thickness of steel being cut.

One size of machine is applicable to small work and die cutting, within a cutting area of 16 in. square, a circle of 18 in., or a rectangular form 12×40 in. may be cut by extension of the tracing table. With this machine, a drawing or pattern double the size of the cut to be made is required, the drawing being placed on the tracing table shown at the right in Fig. 246.

Another machine is made for larger, heavier work. It has a double pantagraph frame and is fitted with two cutting torches for making duplicate cuts at the same time, the position

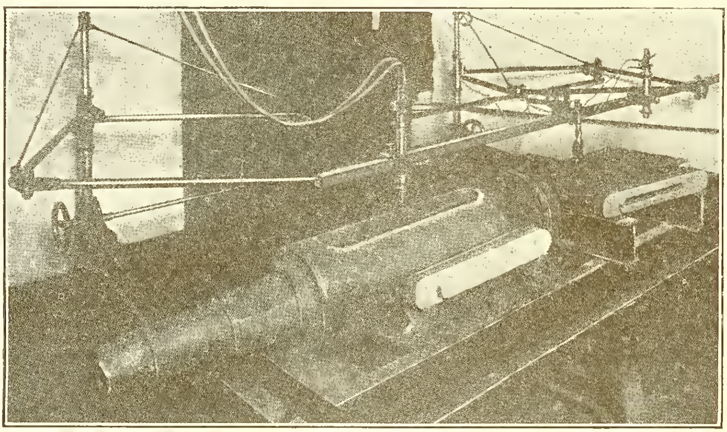


Fig. 248.—Cutting Out a Large Slot.

of the torches and tracing wheel being adjustable. The entire pantagraph frame may be moved backward from the table to allow placing of heavy plate with a shop crane. This machine reproduces the cut of equal size with the pattern, or 1 to 1.

A machine with two pieces of work and pattern in place is shown in Fig. 247.

Another practical application of the Oxygraph is shown in Fig. 248. The piece worked on is a fishing tool used for fishing out broken tubes in oil wells. This Oxygraph has a bed frame 30 in. wide by 9 ft. long. The fishing tool is hollow, with walls $2\frac{1}{2}$ in. thick, and weighs 900 lb. The total cut made of 21 lin. ft. was made in 21 min. or 1 ft. per minute.

CHAPTER XVII

WELDING SHOP LAYOUT, EQUIPMENT AND WORK COSTS

The layout and equipment of a welding shop will, of course, vary with the class and amount of work handled, the capital available, and the personal opinions of the owner. One should, however, have enough equipment of a mechanical nature to insure the finishing of work in a reasonable time without too great an expense for labor. A first class workman can, when necessary, turn out a good job of difficult work with a single welding and cutting outfit; means for preheating which may consist of a few firebrick, asbestos and charcoal; a chisel or two; a good hammer and a few files. These are insufficient, however, where any amount or variety of work is to be handled economically and to the satisfaction of the ordinary run of patrons. A minimum amount of mechanical equipment should include a number of hand and handled chisels, several hammers and sledges of different weights, a portable electric grinder or at least a grinding stand, and a portable electric or a stationary drilling machine, or both. To this, for more extensive work should be added a pneumatic or an electric chipping hammer, a lathe, cranes, and possibly a portable or a stationary motor-cylinder grinding machine. Oil- or gas-burning preheaters are also almost a necessity in any case, while a gas-burning preheater of the table type, will save an enormous amount of time and trouble on the general run of gasoline motor work. Special grated iron welding tables, heavy surface plates and grids, iron blocks and straps and numerous other articles will need to be added as local requirements dictate.

The shop layout for equipment will have to conform to the building unless the shop is built purposely for the work. In this connection very few suggestions of any value can be made, except that the shop manager should endeavor to so place his equipment as to cause the least running back and forth possible.

We will, for the benefit of our readers give the layout of a large shop doing nothing but welding work. This is the shop of the Oxweld Acetylene Co., Newark, N. J., and it was built expressly for this work. Allowance in position had to be made for the set directions of the railroad and street lines.

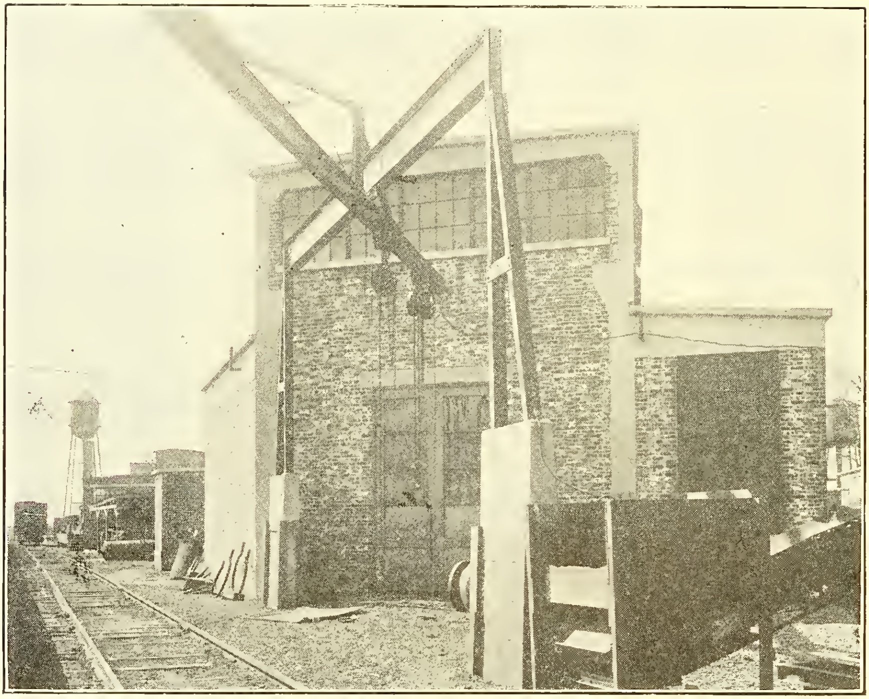


Fig. 249.—Exterior View of Oxweld Shop, Showing Crane Hoists.

Fig. 249 shows the end of the building next to the railroad. The overhead track for the chain blocks is so placed as to be readily used for loading or unloading either cars or trucks. This is good, but a still better arrangement would be to extend the runway on into the shop itself and so save considerable rehandling in order to get the work to or from the welding floor. Fig. 250 is a floor plan showing the location of the various benches, lockers, machines, etc.

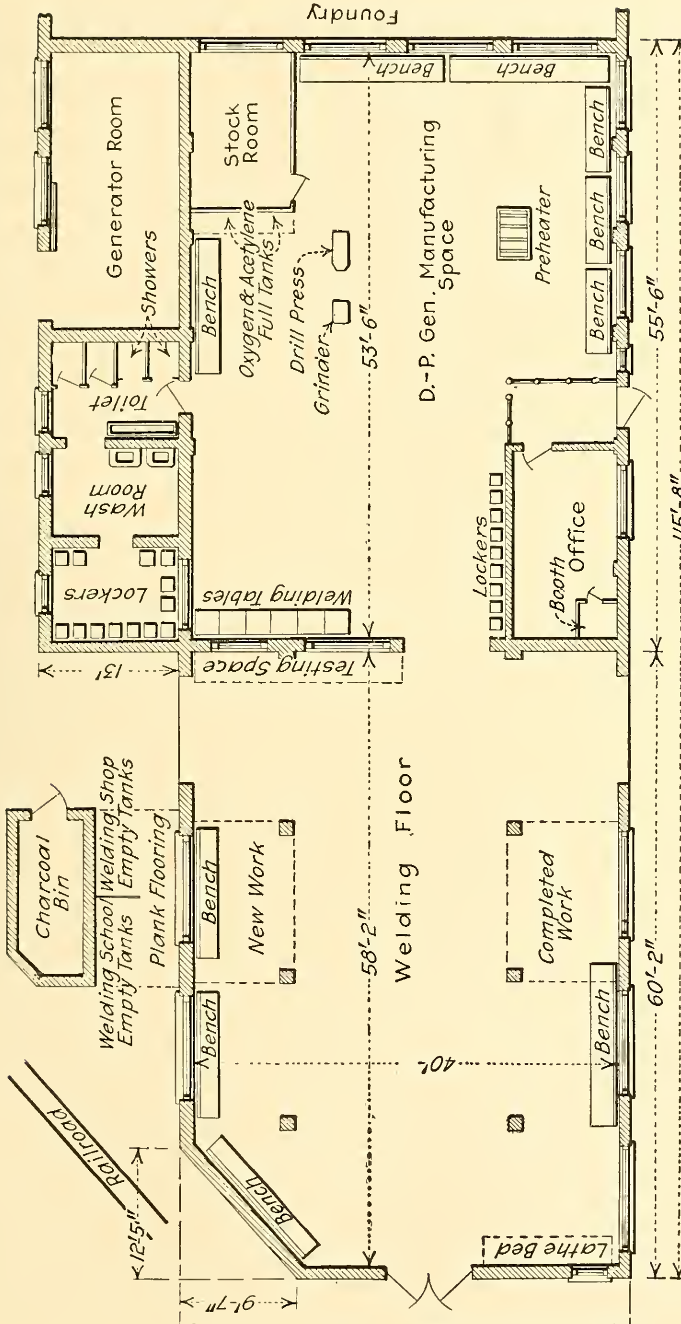


FIG. 250.—Floor Plan of Oxweld Shop.

FIG. 251.—Interior View of Shop.

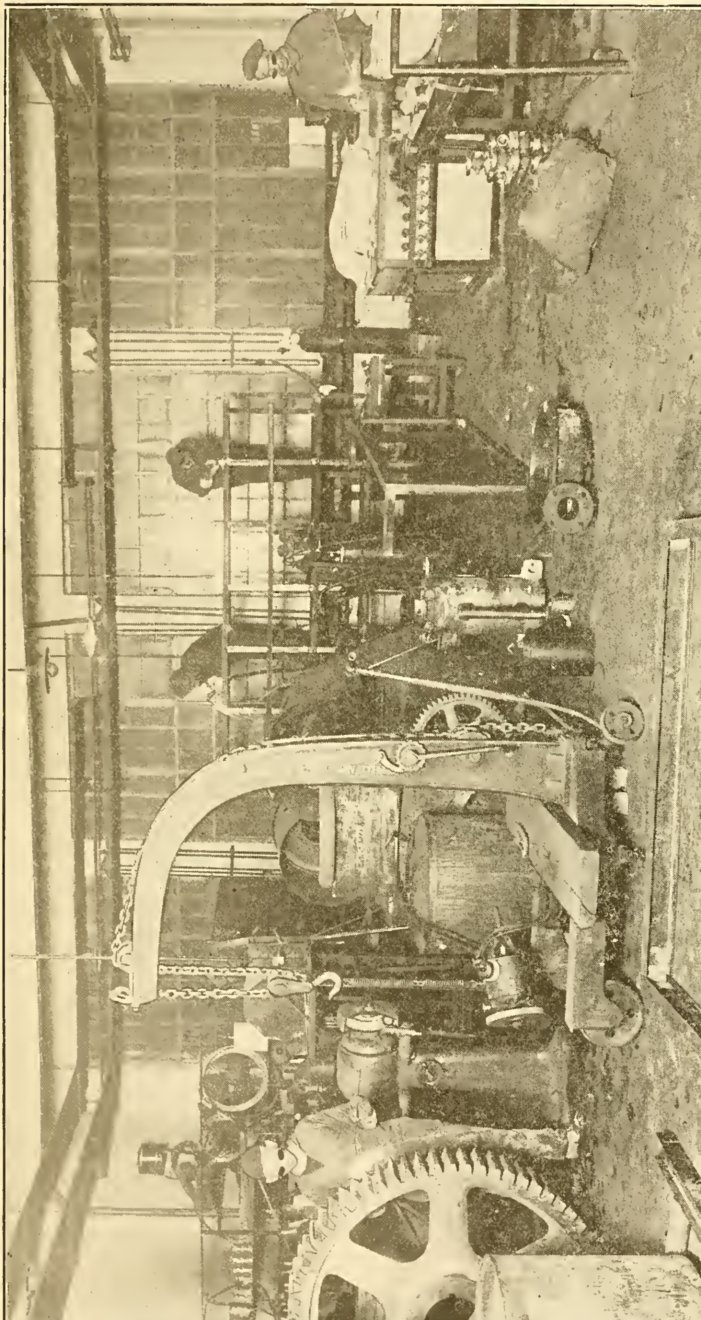


FIG. 252.—Interior View Showing Portable Crane and other Equipment.

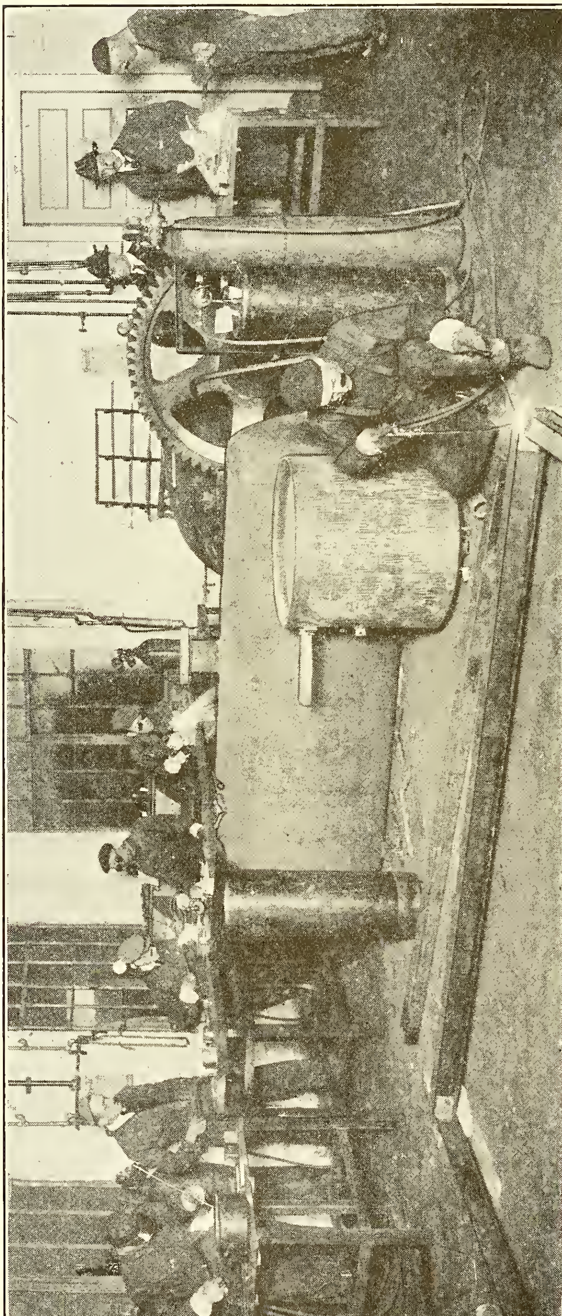


Fig. 253.—View Showing Welding Tables.

In Fig. 251 is shown a view of the shop just inside the northern end. The doors shown at the right are the ones

FORM NO. 671-CM SETS-9-18

WORKING ORDER—WELDING SHOP

JOB No.................... DATE.............................191......

NAME..

ADDRESS..

DESCRIPTION OF WORK REQUIRED..

TIME JOB RATE $..................PER HOUR. GAS, MATERIAL AND EXPENSES EXTRA. INVOICE $....................

CONTRACT PRICE $.................... SALESMAN....................

PAY COMMISSION OF..........% ON $....................AMT. OF COMMISSION $....................

DATE COM. REPORTED....................191......

SHOP TRANSIT

ARTICLE	AMOUNTS USED				TOTAL AMOUNT USED	PRICE	TOTAL COST
CHARCOAL							
OIL PREHEATING							
CAST IRON RODS							
OXWELD IRON WIRE							
ALUM. ROD...... WIRE......							
BRONZE							
BRASS							
FLUX KIND..........							
STEEL ROD KIND..........							
ASBESTOS							
GLOVES							
CARBON, ROD BLOCK							
GOGGLES							
MISCELLANEOUS							
BOARD AND LODGING							
R. R. FARES							
FREIGHT OR EXPRESS							
CARTAGE							

TOTAL COST—SHOP TRANSIT $

REMARKS:

GAS		LABOR				
OXYGEN CU. FT.	ACETYLENE CU. FT.	DATE	WELDER'S NO.	HOURS	RATE	TOTAL
		TOTALS				

INDIRECT CHARGE A/C FOREMAN..........%..........

TOTAL LABOR....................$..........

OVER HEAD....................$..........

GAS	AMT.	PRICE	TOTAL
OXYGEN			$..........
ACETYLENE			$..........

SHOP TRANSIT....................$..........

BASE COST....................$..........

COM. TO SALESMAN....................$..........

PROFIT FOR COMPANY....................$..........

CHARGE CUSTOMER....................$..........

FIG. 254.—Cost Keeping Form.

that open out under the crane shown in Fig. 249. This interior view in Fig. 251 gives a good idea of the lighting and the ventilators at the top for carrying away the fumes. The air and acetylene pipe lines are shown, and in the left foreground is illustrated in the way cylinders are chained. In the central foreground one of the workmen is chipping a casting with a pneumatic chisel.

The opposite end of the shop is shown in Fig. 252. Here a portable crane is shown in the middle foreground. Suspended from it is a portable electric grinding machine. Just back of this is an electric grinding stand. At the right, in the background, is a Wiederwax preheater and just in front of this is an iron preheating and welding stand with an operator at work at it.

At the left in Fig. 253 is shown a number of welding tables with grated cast-iron tops and welded angle- and strap-iron legs. Both the daylight and artificial lighting are excellent throughout the shop. Probably no other shop would be built exactly like this, as conditions differ so radically, but a careful study will reveal to the prospective shop man some of the things that will, or will not, apply to his particular case.

Keeping Track of Costs.—No shop can succeed financially without keeping a close watch on cost of material, gas, labor, overhead, etc. The way this is done in the Oxweld shop will be seen by referring to the form shown in Fig. 254. This is so made as to cover both inside and outside jobs. These forms are made in duplicate on white and pink paper, so that a carbon of the original is made. These forms are for shop and office use only, and from them the customer's bill is easily made out. With forms of this kind, the entire data relating to any job may be had at any time by reference to the files.

Another form of cost card, suggested by the Imperial Brass Manufacturing Co., is shown in Fig. 255. This is not so complicated as the form just given, and will answer in many cases. The manager should not forget, however, to add to this the cost of overhead, which it is wise to make fairly high to allow for contingencies—say from 100 to 150 per cent.

Carbon Burning.—While carbon burning has nothing to do with welding, the ordinary welding shop is often called upon to do such work on account of having a supply of oxygen at hand.

Carbon in a motor cylinder is caused by imperfect combustion. It may be that the carburetor was not adjusted so as to give sufficient air, or it may be too much oil was used. The use of oxygen is the most practical and thorough way to remove this deposit.

Oxygen gage, start	1800 lbs.=100 cu. ft.	
Oxygen gage, finish	900 lbs.= 50 cu. ft.	
Oxygen used	900 lbs.= 50 cu. ft.	
Acetylene used:		
50 cubic feet	@ $0.025	$1.25
Oxygen used:		
50 cubic feet	@ .02	1.00
PREHEATING COST		
Charcoal		
Gas, ½ hour, 2 burners	@ .60	.30
Kerosene		
LABOR (Preparing):		
1 hour 30 min.	@ .60	.90
LABOR (Welding):		
1 hour 30 min.	@ .60	.90
LABOR (Finishing and testing):		
1 hour min.	@ .30	.30
RODS:		
Lbs. Steel	@	
15 Lbs. Cast Iron	@ .10	1.50
Lbs. Bronze	@	
Lbs. Copper	@	
Lbs. Aluminum	@	
FLUX:		
½ Cans Cast Iron	@ .50	.25
"		
"		
"		
"		
		Total $6.40
REMARKS		

FIG. 255.—Suggestion for Cost Card.

A decarbonizing outfit is shown in Fig. 256. Here *A* is the oxygen tank valve, *B* the tank coupling, *C* the pressure gage showing the pressure at which the oxygen is delivered to the "torch," *D* the regulating screw, *E* hose connection, *F* trigger valve, *G* hose connection and *H* the flexible copper tip.

To use this outfit, connect it up as shown, then with the motor running shut off the gasoline and let the motor run down. If the engine is particularly dirty, it may be advisable to protect the carburetor and pan by placing some asbestos paper at points to prevent fires from flying sparks.

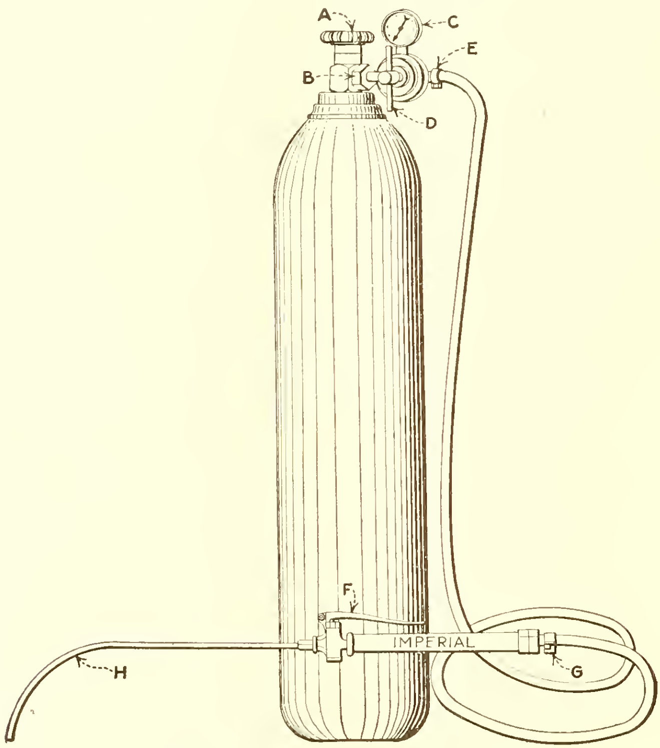


Fig. 256.—Imperial Decarbonizing Outfit.

Remove spark plugs from cylinders—not the valve caps. Crank the motor until the cylinder to be started upon has the piston at the top, with both valves closed.

Set the pressure on the regulator at about fifteen pounds and partially depress the lever on the handle of the carbon burner.

Use a wax taper or drop a lighted match into the spark plug opening of cylinder, at the same time directing the copper tube of the carbon burner at that point. This ignites the carbon, and if it is not too dry, the oxygen should thereafter be sufficient to completely consume it without again lighting it. At the start, particularly if the cylinder is oily, there will be some flame as well as considerable sparks. Hold the pressure down until the flame has practically disappeared, then press down the lever all the way and move the nozzle back and forth around the walls until sparks stop.

Sometimes the cylinder is very dry and the carbon is rather difficult to burn. This can be more or less determined by the appearance of the spark plug. If it is dry, squirt about a teaspoonful of kerosene into the cylinder, spreading it over as large a surface as possible, to aid the burning.

The copper tube is flexible and may be bent as desired to reach any portion of the cylinder. Actual contact with the carbon by the tube is not necessary to consume it—carbon burns in an atmosphere of oxygen after it is ignited.

The only possible danger to the cylinder, valves or piston is a too high pressure of oxygen on an extremely oily cylinder —there would be considerable heat generated in this instance. Hold the pressure down, then, until the flames have gone and sparks only are being thrown out before fully opening the lever on the handle.

When through cleaning, it is desirable to remove the valve cap and blow out any solid particles there may be present; these solid particles cannot be carbon, but may be pieces of iron, etc. The appearance of the cylinder will be considerably improved by swabbing off the top of the piston and valves with an oily rag.

Carbon burning is a very practical solution of carbon deposits—but care and horse sense must be used, though the process calls for no particular degree of skill.

SAFETY RULES FOR GAS-TORCH WORKERS

The following rules were adopted in 1920 by the Western Pennsylvania Division of the National Safety Council:

Equipment Rules

1. All pressure tanks should be fitted with safety relief devices, and tanks not so equipped should not be used.

2. The equipment should include a high-pressure gage to indicate the pressure on the tank, a reducing valve, and a low-pressure gage to indicate the pressure on the torch. These should be assembled as one unit and so arranged that they need not be separated when they are attached to, or detached from, the tank. The two gages should have different-sized openings; one should have a right-hand thread and the other a left-hand thread so that they cannot be interchanged. There should be one of these units for the oxygen tank and one for the acetylene tank.

3. All pressure regulators should be equipped with a safety relief valve which will relieve the pressure from the diaphragm and low-pressure gage in case the high-pressure valve should develop a leak.

4. Wire-wrapped hose should not be used.

5. The oxygen and acetylene hose should be of different color or the couplings should be stamped for identification purposes, so as to avoid interchanging the hose.

6. The torches should be of a type which will not backfire.

Rules for Operation

1. Under no condition should acetylene be used where the pressure is greater than 15 lb. per square inch.

2. Special care should be given to the storage of oxygen and acetylene tanks. Acetylene is classed as an explosive, and only a limited number of containers should be stored in any one place. Oxygen tanks should be stored in a separate place from acetylene tanks.

3. Oxygen and acetylene tanks should not be allowed to remain near stoves, furnaces, steam heaters or other sources of heat, and should not be exposed unnecessarily to the direct rays of the sun, as an increase in the temperature of the gas will cause a corresponding increase in the pressure within the tank. Any excess of heat may also soften the fusible safety disk with which the tank is provided, causing it to blow out and permitting the gas to escape.

4. Oxygen tanks should never be handled on the same platform with oil or grease which might find their way into the valves on the tanks.

5. Oxygen and acetylene tanks should never be dropped nor handled roughly, and should never be stood on end unless fastened so as to prevent them from falling over.

6. Tanks should not be handled by crane, either magnetic or mechanical.

7. All empty tanks should be marked plainly with the word "empty" and returned promptly to the storeroom.

8. An open flame should never be used for the purpose of discovering leaks in acetylene tanks. Leaks can generally be detected by the odor of the acetylene gas, and their location can be determined by applying soapy water to the surface of the tank and watching for the soapy bubbles formed by the escaping gas.

9. No repairs to oxygen or acetylene tanks or equipment should be

made or attempted. All defects should be reported promptly to the foreman, and by him to the manufacturer.

10. Leaking acetylene tanks should not be used, but should be placed in the open air and all open lights be kept away from them. All leaking acetylene tanks should be reported promptly to the foreman and immediately returned to the manufacturer.

11. All open flames should be kept away from any place where there is any possibility of acetylene escaping.

12. Care should be taken to protect the discharge valves of tanks from being bumped, as a jar may damage the valve and cause it to leak.

13. Grease in contact with oxygen under pressure may cause spontaneous ignition. Great care should be taken not to handle threads or valves with oily hands or gloves, and gages should not be tested with oil or any other hazardous carbon. If a lubricant must be used, the purest glycerine is permissible.

14. Gages, apparatus and torches requiring repairs should be sent to the manufacturer, and local repairs should not be attempted. Valve seats should never be replaced except by the manufacturer.

15. The use and operation of the pressure regulator or reducing valve on oxygen or acetylene tanks should be as follows: (a) Open the discharge valve on the tank slightly for a moment and then close it. This is to blow out of the valve any dust or dirt that might otherwise enter the regulator. (b) By means of the stud or nut connection on the regulator, connect the regulator to the discharge opening of the tank. (c) Release the pressure-adjusting screw of the regulator to its limit. (d) Open the needle valve slightly if there is one. (e) Open the discharge valve on the tank gradually to its full width. (f) Open the needle valve to its maximum if there is one. (g) Adjust the pressure-regulating screw until the desired pressure is shown on the low-pressure gage.

16. The discharge valves on the tanks should be opened slowly, and care should be taken to avoid straining or damaging them by the use of a hammer or the wrong kind of wrench. A special wrench should be made for use in opening these valves in case they stick.

17. When the operation of the cutting or welding torch is stopped for a short time, the needle valve on the regulator should be closed, or the pressure-adjusting screw should be released to keep the pressure off the hose. The torches should be opened momentarily to let the pressure out of the hose lines.

18. All tanks should be inspected at the close of the day's work.

19. Proper precautions should be taken to protect the hose from flying sparks.

20. All hose should be examined periodically at least once every week. This should be done by cutting the hose off at the end of the connection and examining it. In addition, after a few months' use, the hose should be cut off about two inches back of the connection and examined for defects. A defective hose should never be used.

21. Special care should be taken to avoid the interchange of oxygen and acetylene hose or piping, as this might result in a mixture of these gases that would be highly explosive. The practice of using right- and left-hand threads is recommended.

22. White lead, grease, or other similar substances should never be used for making tight joints. All joints and leaks in equipment should be made tight by soldering or brazing.

23. The oxygen and acetylene valves at the base of the torch should be tested daily for leaks.

24. Where hydrogen or other gas is used instead of acetylene, the same precautions should be observed as for acetylene.

25. A fire extinguisher should be carried as regular equipment to be used in case of fire.

26. Men using welding apparatus should wear suitable welding goggles for eye protection, having frames that are nonconductors of heat (not celluloid), side shields to protect against hot particles of metal, and lenses of proper color.

27. Operators' clothing should be fireproof.

28. If valves become frozen, they should be thawed by hot water, not by flame or hot metal rod.

29. Home-made generators should never be used, as they are unsafe. Only generators permitted by the Board of Underwriters should be used.

30. Where acetylene is used from generators or is piped through the plant, an approved water seal should be interposed between the generator and the piping system, and individual water seals should be placed at each blow-pipe. Water seals should be inspected daily without fail.

31. Portable generators should not be used inside the building.

32. Safety devices on tanks, generators, or apparatus should not be removed or tampered with.

33. In welding brass or bronze, injurious fumes may be given off, making it desirable to wear a respirator.

34. Smoking while on duty should be prohibited.

35. Electric lights in a generator house should be enclosed in vapor-tight globes protected by the regular guards.

36. Snap switches should be placed outside of the generator house in a suitable place, provided the house is isolated.

37. Piping which is used to carry acetylene or hydrogen should be painted a distinctive color.

38. The manufacturers should provide couplings for the hose which cannot be mistaken and put on the wrong hose. If the couplings could be made only with the proper connections, it would be impossible to make a mistake.

39. In storage houses where hydrogen or acetylene tanks are stored, the wiring should conform to the same rules as for the generator house, so that an explosion could not be caused by defective wiring or a break in the bulb.

40. The valves on the piping should contain neither copper, brass, nor bronze.

41. In opening the outlet valve of a full tank, do not remove the regulator.

42. The operator should not stand in front of the gages when opening the discharge valves on the tank. If the pressure goes off suddenly, it may possibly destroy the gage and the glass, and parts will be blown out at the front.

43. A label should be placed on every tank of oxygen, stating that it should be kept away from grease.

RULES FOR WELDING

The following rules, adopted by the Committee on Standards for Locomotives and Cars, U. S. Railway Administration, for the purpose of preventing the abuse of autogenous welding for purposes for which it is not well adapted, have been sent to the regional directors by Frank McManamy, assistant director of the Division of Operation, with instructions to direct all roads to observe the rules in the construction or repair of locomotive boilers, so that any failures which may have been caused or contributed to by unrestricted or improper use of autogenous welding may be prevented.

1. Autogenous welding will not be permitted on any part of a locomotive boiler that is wholly in tension under working conditions, this to include arch or water bar tubes.

2. Staybolt or crown stayheads must not be built up or welded to the sheet.

3. Holes larger than 1½ in. in diameter when entirely closed by autogenous welding must have the welding properly stayed.

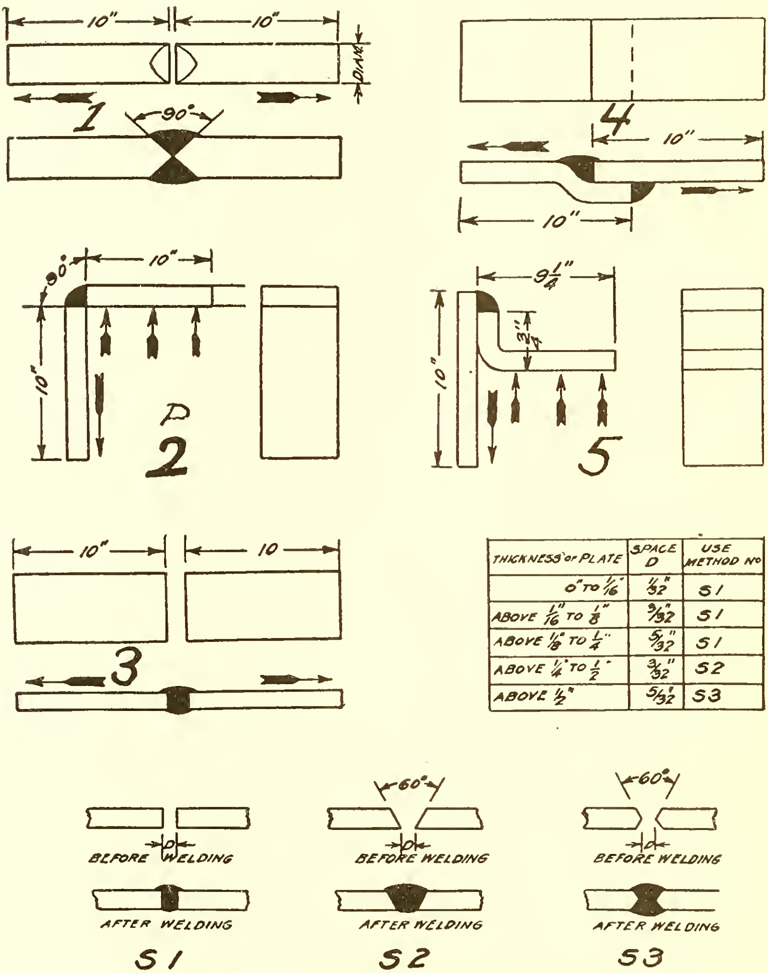
4. In new construction welded seams in crown sheets will not be used where full size sheets are obtainable. This is not intended to prevent welding the crown sheet to other firebox sheets. Side sheet seams shall not be less than 12 in. below the highest point of the crown.

5. Only operators known to be competent will be assigned to firebox welding.

6. Where autogenous welding is done the parts to be welded must be thoroughly cleaned and kept clean during the progress of the work.

7. When repairing fireboxes a number of small adjacent

patches will not be applied, but the defective part of the sheet will be cut out and repaired with one patch.



THICKNESS OF PLATE	SPACE D	USE METHOD NO
0" TO 1/16"	1/32"	S1
ABOVE 1/16" TO 1/8"	3/32"	S1
ABOVE 1/8" TO 1/4"	5/32"	S1
ABOVE 1/4" TO 1/2"	3/32"	S2
ABOVE 1/2"	5/32"	S3

Fig. 257.—Kinds of Welds Tested and Examples Used as Welding Guides.

8. The autogenous welding of defective main air reservoir is not permitted.

9. Welding rods must conform to the specifications issued by the Inspection and Test Section of the United States Rail-

road Administration for the various kinds of work for which they are prescribed.

STRENGTH OF OXY-ACETYLENE WELDS

The results of tests made by the Welding Committee of the Emergency Fleet Corporation, on oxy-acetylene welds of

TABLE XVIII.—STRENGTH OF OXY-ACETYLENE WELDS

Mark	Size	Kind of Weld	Ultimate Strength	Strength Per Sq. In.	Per Cent.	Av. Per Cent.	Break In
1	1″ Sq.	Butt	50600	50600	92.		Weld
2	"	"	50235	50235	91.	91.	"
3	"	"	49795	49795	90.		"
1-514	1″ Dia.	"	43315	55000	100.		"
1-515	"	"	44885	56900	100.	100.	"
1-513	"	"	45160	57400	100.		"
1-511	2″ Dia.	"	155520	47500	86.5		"
1-512	"	"	149515	46800	85.2	86.4	"
1-510	"	"	153900	48200	87.5		"
2-516	$\frac{1}{8}\times1\frac{1}{2}''$	R. Ang.	7515	40000	73.		Bar
2-517	"	"	7645	40500	73.5	74.2	"
2-518	"	"	7915	42000	76.3		"
2-519	$\frac{1}{4}\times1\frac{1}{2}''$	"	12605	33600	59.2		Weld
2-520	"	"	12820	34000	61.5	59.9	"
2-521	"	"	12150	32300	59.0		"
3-525	$\frac{1}{8}\times1\frac{1}{2}''$	Butt	10890	58000	100.		Bar
3-526	"	"	10775	57500	100	100.	Weld
3-527	"	"	10935	68500	100.		Bar
3-522	$\frac{1}{4}\times1\frac{1}{2}''$	"	21460	57000	100.		Bar
3-523	"	"	22025	58600	100.	98.8	Bar
3-524	"	"	20785	53300	96.5		Weld
4-528	$\frac{1}{8}\times1\frac{1}{2}''$	Lap	10970	58500	100.		Bar
4-529	"	"	10725	57500	100.	100.	Bar
4-530	"	"	10965	68600	100.		Bar
4-531	$\frac{1}{4}\times1\frac{1}{2}''$	"	21905	59300	100.		Bar
4-532	"	"	22085	58700	100.	100.	Bar
4-533	"	"	21435	57000	100.		Bar
5-537	$\frac{1}{8}\times1\frac{1}{2}''$	Tank	2495	13300	24.6		Bar
5-538	"	"	2210	11750	21.4	22.6	Bar
5-539	"	"	2760	12106	22.		Weld
5-534	$\frac{1}{4}\times1\frac{1}{2}''$	"	4936	13100	23.8		Weld
5-535	"	"	5675	15100	27.4	26.3	Bar
5-536	"	"	5196	15600	24.7		Weld

various kinds are given in Table XVIII. The 1 and 2 in. bars were of machine steel, turned to size before testing. The sheet was steel ship plate. The careful engineer will find some rather puzzling discrepancies in this table, but it is the best available at the present time. The key numbers of the various specimens will be found to correspond to the types of welds illustrated in Fig. 257. At the bottom of this illustration will be found examples used as guides for welding different joints, the thicknesses of the plates and end-spaces being indicated in the table just above the examples. The arrows in the illustrations of the test welds indicate the direction of pull.

STRENGTH OF OXY-ACETYLENE WELDED PIPE

The Linde Air products Co., Buffalo, N. Y., report that they made some tests in their laboratory in 1920, to determine the strength of welded pipe. These tests were intended to prove to a large user of oil pipe from Kansas, that properly welded pipe will not break at the weld under pressure.

According to the report made, the Linde engineers welded together two short sections of standard 3-in. iron pipe, threaded the ends and screwed on two standard cast-iron caps. When the cold water pressure test was applied to the breaking point, the top of one of the caps blew out, leaving the pipe and weld intact. The undamaged cap and the remaining portion of the broken cap were then removed and two extra heavy iron caps were screwed on. At a pressure of 6,200 lb. per sq. in. one of these caps let go, still without injury to the weld or the pipe. Again the uninjured cap and remnant of the broken one were taken off and extra heavy steel caps screwed on. This time the caps held, but the pipe split and ripped under the added pressure upon passing the elastic limit, tearing up to, and being effectually stopped by, the weld which refused to give.

The next test was made with 4-in. pipe. Two lengths were welded together, the ends threaded and two extra heavy standard caps screwed on. In this test one of the cap heads blew out at 4,400 lb., which gave a total end pressure on the cap of approximately 33 tons, proving that the broken cap was not in any respect defective. The weld was not impaired at all. After this test it was suggested that an entirely new weld with other pipe lengths of the same diameter be tried. Accordingly two more lengths of 4-in. pipe were welded, threaded and sealed, this time with extra heavy steel caps made to withstand a working pressure of 3,000 lb. of air. The pressure was applied and the pipe gave way in the threads at 4,200 lb. In all of the tests the welds held securely.

PART II—THERMIT WELDING

CHAPTER I

THERMIT WELDING: ITS HISTORY, NATURE AND USES

The affinity of finely powdered aluminum for oxygen, sulphur, chlorine, etc., is such that it is utilized to effect a reduction of metals from their respective oxides, sulphides and chlorides. This was known for many years and is generally credited to Frederick Wohler. About 1894 Claude Vautin found that when aluminum in a finely divided state was mixed with such compounds and ignited, an exceedingly high temperature was developed by the rapid oxidation of the aluminum. Since fine aluminum will not burn at a temperature below that of molten cast iron Vautin and others first heated the mixtures in a crucible. The result was that the initial temperature was so high at the moment of ignition that the reaction was explosive.

Profiting by the experiments already made, Dr. Hans Goldschmidt of Essen, Germany, discovered a method of igniting a cold mixture of fine aluminum and iron oxide by means of a barium-peroxide fuse which was set off by means of a storm match. His first discovery was made about 1895 or 1896 while trying to reduce chromium and manganese. Later magnesium powder or ribbon was used for ignition purposes, being set off in the same way. A mixture of a few pounds of the powders was found to burn quickly and the resulting temperature was very high. The original patent for the reduction of metals, upon which all his following patents were founded, was granted March 16, 1897, the serial number being 615,700. Over 40 have been issued since and more are pending. About 1898 Dr. Goldschmidt made used of his reduction method to weld two pieces of iron together. From this time on the experiments developed and difficulties were overcome until a process was evolved for the commercial use of the reaction for welding and other purposes. The process so developed was called the Thermit process. The company handling the mixtures and apparatus was originally known as the Goldschmidt Thermit Co., but in 1918 the name was changed to the Metals and Thermit Corporation, New York.

The present Thermit reaction is $8Al+3Fe_3O_4=9Fe+4Al_2O_3$. Expressed in weights this is 217 parts aluminum plus 732 parts magnetite=540 parts steel plus 409 parts slag, or approximately 3 parts of aluminum plus 10 parts of magnetite will produce on combustion 7 parts of steel. The steel produced by the reaction represents about one-half of the original Thermit by weight and one-third by volume.

Commercial Thermit is a mixture of finely divided aluminum and less finely divided magnetic iron scale. The aluminum is about like granulated sugar and the scale like coarse sand, the ratio by weight being approximately three of iron scale to one of aluminum.

According to the company just mentioned the average analysis of Thermit steel is:

Carbon	0.05 to 0.10
Manganese	0.08 to 0.10
Silicon	0.09 to 0.20
Sulphur	0.03 to 0.04
Phosphorus	0.04 to 0.05
Aluminum	0.07 to 0.18

Of course to produce a steel of the foregoing composition the aluminum and iron scale must be very pure. For the mixture, scale from Bessemer or open-hearth steel would probably come close to meeting commercial demands. The average tensile strength of a Thermit weld of the foregoing average composition is about 61,000 lb. per square inch. This can be varied by adding other elements. The elastic limit is slightly more than half this figure, or an average of about 34,000 pounds.

Temperature and Characteristics.—While the temperature of the reaction is too high to be measured by a pyrometer it can be calculated quite accurately theoretically and Prof. Joseph W. Richards in his book "Metallurgical Calculations," gives it as 2694 deg. C., which is equal to 4881 deg. F.

M. Féry, using his radiation pyrometer, found the temperature of the stream of steel as it issued from the crucible to be 2300 deg. C. (4172 F.). Making allowance for the chilling effect of the crucible this is probably about right. Considering the melting point of steel to be about 1350 deg. C., Thermit steel is nearly twice as hot.

There is absolutely nothing explosive about the present Thermit reaction and no danger is incurred in storing it or handling the material owing to the fact that it takes over 1300 deg. C. of heat to ignite it. It is for this reason that a special ignition powder must be used for starting the reaction. The ignition powder, however, must be kept away from heat, and in particular the box containing it should be tightly closed before the Thermit reaction takes place, so as to prevent any spark from dropping into it. All Thermit materials must be kept dry, for Thermit that has once become wet cannot be restored to its original condition by drying.

Plastic and Fusion Methods.—There are two different methods of using Thermit for welding purposes. For convenience these methods may be designated (1) the plastic method and (2) the fusion method. The first is used principally for welding together the ends of pipes. Here the pipe ends are first machined off so that they will fit snugly together. A mold is then placed around the ends, and Thermit is poured into the mold from a crucible. The Thermit mixture is first placed in the crucible and ignited by means of a small amount of ignition powder set off by a match. After the reaction the molten content of the crucible is poured into the mold and around the pipe ends. By pouring from the top of the crucible the slag enters the mold first and surrounds and coats the pipe ends and the inside of the mold and thus prevents the pipe ends from being burned through. This allows the Thermit to heat the pipe ends to a welding heat, after which they are forced together, causing a slightly upset welded joint.

The second, or fusion method, is the more commonly used. In using this method a mold is also used to surround the parts to be welded, but the parts must be preheated—usually to a red heat—in order to prevent the Thermit being chilled by contact with the colder metal and causing an imperfect weld. The Thermit to be used is placed in a cone-shaped crucible so made that the melted Thermit steel may be run out of the bottom into the mold, thus preventing the slag from getting into the mold and spoiling the perfect fusion of the parts. In this method it is also necessary to have the parts to be welded some distance apart in order to give the Thermit steel an opportunity to properly fuse the surfaces desired and produce a perfect union. The distance the parts are separated depends on the size and nature of the pieces and whether the weld is to be made on two separate pieces or is merely to weld a cracked place.

This last method is especially adapted for welding together large heavy parts of considerable section, on account of the Thermit steel being produced and introduced into the weld quickly in bulk and thereby resulting in but one contraction throughout the entire mass of metal. Provision to compensate for this contraction can always be made, so that when the metal cools there will exist practically no strains. Welds requiring as high as 4000 lb. or more of Thermit have been completed successfully. A big advantage of the process is that huge welds may often be made without dismantling the machine or structure, thus saving an enormous amount of labor and time in many cases.

Neither method, however, is commercially or practically adapted to welding very small sections or long seams in thin sections, which work can be better accomplished by the oxy-acetylene or electric welding processes. It should, however, be used for welding shafts when the break is in a journal. It is interesting to note in this connection that neither the oxy-acetylene nor the electric welding processes has proved practical for welding trolley rails together. All so-called welded joints by those methods consist merely in welding plates to the rails and the joint therefore is never really eliminated. The Thermit process, on the other hand, has proved extremely efficient and economical for this work, and thousands of Thermit-welded rail joints have been in service for years in all parts of the world.

Kinds of Thermit Commonly Used.—For commercial welding purposes there are now produced three varieties of Thermit known as:

Plain Thermit.

Railroad Thermit.

Cast-iron Thermit.

Plain Thermit is simply a mixture of aluminum and iron oxide, as previously stated, and is used in making pipe welds and welding necks on mill rolls and pinions where the Thermit is merely used as a heating agent to bring the pipe ends up to a welding temperature and the roll and pinion ends to a molten state.

Railroad Thermit is plain Thermit with the addition of $\frac{5}{8}$ per cent. nickel, 1 per cent. manganese and 15 per cent. mild-steel punchings. This grade is used in connection with steel welds.

Cast-iron Thermit is plain Thermit with the addition of 3 per cent. ferrosilicon and 20 per cent. mild-steel punchings, and is used, as its name implies, for welding cast-iron parts.

CHAPTER II

MAKING PLASTIC PROCESS WELDS

Taking up now the various uses of the three varieties of commercial Thermit we will first describe in detail the butt welding of pipe. This is done by the plastic process which is especially adapted to welding joints in the pipes in refrigerating plants and for high-pressure steam, hydraulic or compressed-air pipe lines. It is also applicable to the welding

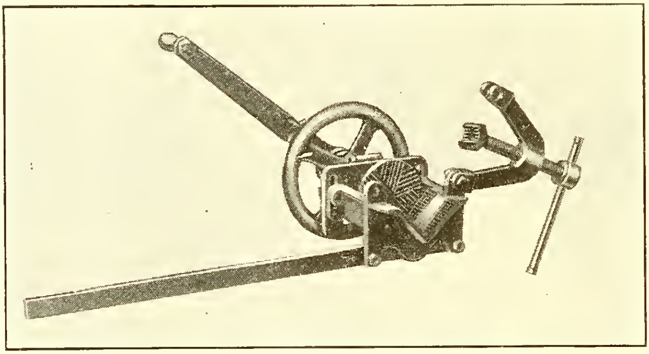


Fig. 1.—Pipe-Facing Machine Open to Receive Pipe.

of superheater units for locomotives. The joints so welded are permanent, nonleakable and never require attention, and the original cost compares very favorably with that of the special mechanical joints of any type used for refrigerating or high-pressure purposes. All of the apparatus necessary for the work is easily portable, so that the work may be done anywhere.

In preparing pipe for butt welding it is first necessary to insure that the ends are cut square. If the pipe is threaded the threaded portions will have to be cut off. While the ends of the pipe may of course be squared by various mechanical

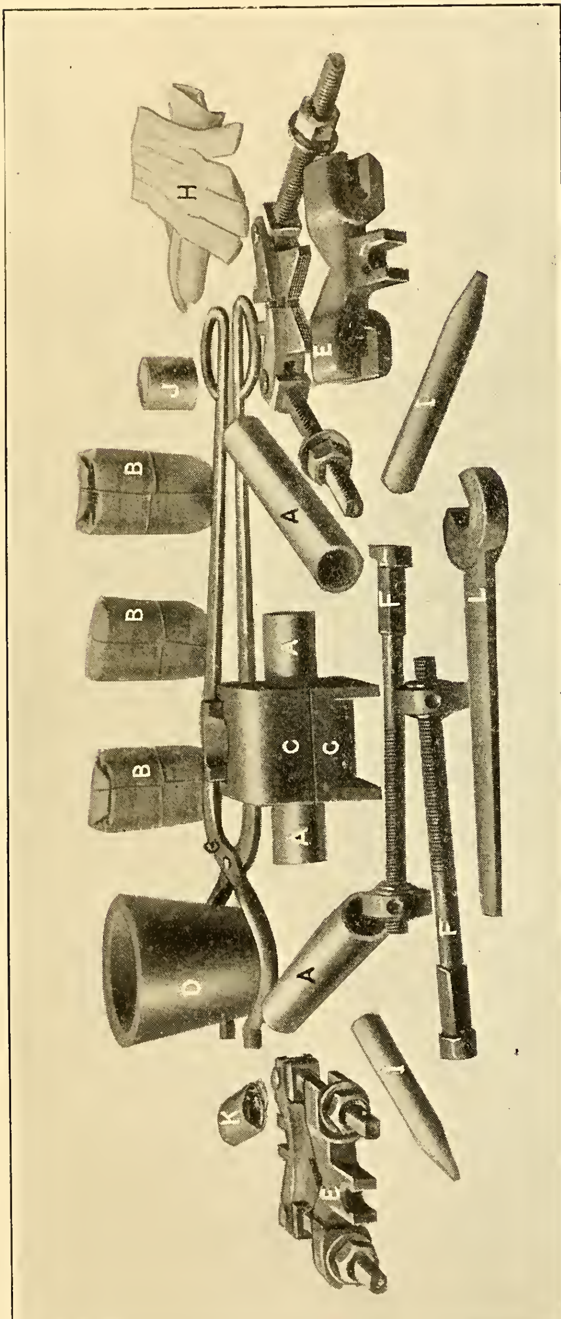


FIG. 2.—Materials for Welding Pipe.

means the company handling Thermit makes a small portable machine for the purpose, which is much more satisfactory to use than anything else. This device is shown in Fig. 1. The operation of this machine is so obvious to any mechanic that further explanation of its operation and method of use would be needless, except to say that the crank handle by which the cutter is rotated has a ratchet on it so that the cutter may be worked in close quarters.

If after the pipe ends have been faced off they should become tarnished they should be brightened with clean, fine emery cloth or a flat carborundum stone, but in no case should the faced ends be touched with a file or the fingers.

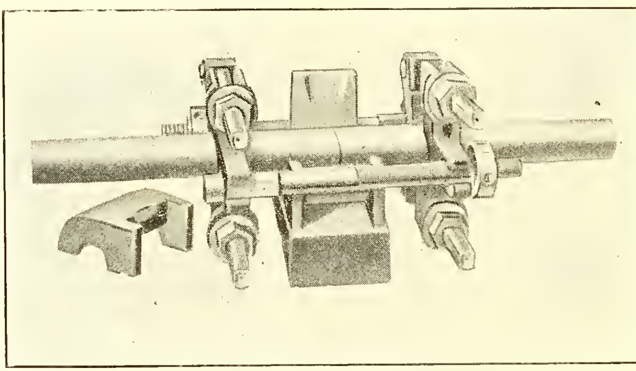


Fig. 3.—Pipe Held in Clamps, Mold Partly Assembled.

When the pipe ends have been properly faced off, the pipe is lined up so that the faced ends will butt squarely together and then the mold is put in place. In welding coils or bends suitable apparatus should be rigged up to keep the pipe in alignment. Where the pipes are close together in coils it is usually possible to spring out the pipe to be welded so as to permit the adjustment of the mold and clamps.

A Pipe-Welding Outfit.—A complete outfit for welding pipe, less the facing machine, is shown in Fig. 2. In this cut, pieces of pipe are shown at *A*; welding portions of Thermit at *B*; cast-iron mold at *C*; at *D* is the magnesia-lined crucible; *E*, clamps; *F*, turnbuckles for clamps; *G*, crucible tongs; *H*, gloves; *I*, pins for tightening turnbuckle nuts; *J*, ignition powder; *K*, dark glasses, and *L*, wrench for tightening nuts of clamps. In order to make the procedure clearer a pipe-mold and clamp unit is shown in Fig. 3. Here the pipe is shown securely clamped in place with the ends butting together. When putting this apparatus in place the clamps are first adjusted at an even distance from the ends of the pipe and securely clamped. The two tension bolts are then adjusted so as to bring an even bearing all around on the pipe ends, but care must be taken not to put such a tension on the pipe that it will buckle when heated. Just enough tension to hold the ends securely is all that is needed. It will be seen that while a set of clamps may be used for a number of sizes of pipe a mold can only be used for the size for which it was made.

How the Mold is Used.—The lower part of the mold is

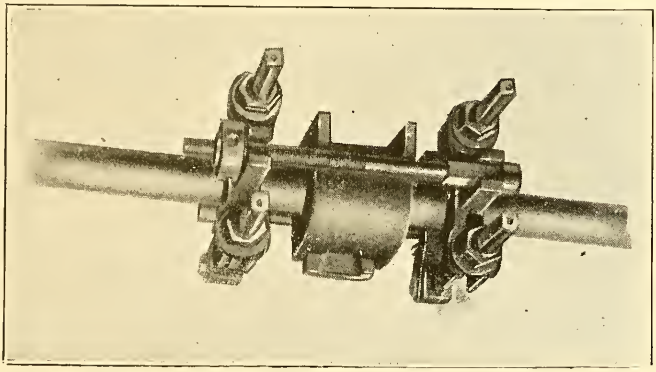


Fig. 4.—Mold Fully Assembled for Weld.

shown in place, but the top part of the mold is shown at the left ready to be put on. The slightly beveled recesses in the top and bottom parts of the mold are for the pouring gate. Before putting the top part of the mold in place care must be taken to see that the lower part is blocked up or held so as to be in close contact with the pipe. This may be done by means of wedges, earth or any other means at hand that will stay in place during the process. With the top part of the mold in place, as shown in Fig. 4, the operator next prepares the Thermit for pouring. This is done by placing the crucible tongs on the ground convenient to the mold and then setting the crucible in the jaws of the tongs. It is very important that the crucible be thoroughly dried before using, and if it is a new crucible it is advisable to burn a pound or so of Thermit in it and then pour the contents out on dry sand. This is the quickest and most convenient way of drying a crucible. The operator should have the handles of the tongs placed toward him convenient for pouring the metal when the reaction is completed. If double tongs are used, as sometimes is necessary with large crucibles, the helper should stand opposite the operator in readiness to help pick up the crucible at the proper time. Blue or special glasses should be worn to protect the eyes from the glare of the reaction.

As each size of pipe must have its own size of mold so must the portions of Thermit be measured out in order to have the proper amount for a given size of pipe. This is taken care of by the concern making the Thermit, which puts it into bags, each containing a certain amount of Thermit suitable for a given welding job. For all ordinary jobs this scheme makes it unnecessary for the operator to do any special calculating in order to know how much to use in order to do the work and not waste material.

Placing and Igniting the Thermit.—With a bag containing the proper amount of Thermit the operator pours about one-half into the crucible and the rest in a hand scoop for feeding into the crucible during the reaction. Having therefore one part of this portion in the crucible and the remainder in a scoop he places a half spoonful of ignition powder (barium peroxide) in one spot on top of the Thermit in the crucible. This is set off by means of a parlor match, which is applied immediately after striking and before the head is burned off, to the ignition powder itself or else to another match head set into the ignition powder.

The ignition of the powder in turn starts the Thermit reaction. After the reaction is well started the operator adds the rest of the Thermit from the scoop, trying to keep about one-half of the surface of the molten material covered with unburned Thermit, and pouring in a steady stream until all the Thermit is in the crucible. He should then immediately grasp the crucible with the tongs, obtaining a firm grip, and pour the contents into the mold, the slag entering first. The pour should be made as soon as the Thermit has reacted and the slag has come to the top. The crucible and tongs are then set aside and a short time is allowed to elapse for the Thermit mass to bring the ends of the pipe to a welding heat. Shortly after pouring the operator should turn the tension nuts enough to keep a constant pressure to determine when the pipe begins to soften. He should then wait for 10 to 20 sec., depending on the weight of pipe, and then force the ends together by means of four quarter turns (one complete revolution) of the nuts. It usually takes about 10 sec. from the time the pipe softens for it to reach a welding heat, or from 45 sec. to $1\frac{1}{2}$ min. from the time of pouring.

Removing the Mold.—After the clamps have been drawn up, the mold should be allowed to remain in place for 3 or 4 min. longer, after which the clamps can be removed and the cast-iron mold knocked away from the pipe by means of a hammer. The Thermit steel and slag will come away from the pipe with the mold and can be knocked out of the mold afterward.

Care must be taken in every case that a complete welding portion be used, as only the full measure of Thermit will give a good weld.

It is advisable where joints are being welded in quantities to have several molds so as not to use molds continuously while hot. It is also advantageous to allow the mold with its contents of steel and slag to remain on the pipe for a considerable time before removing. If they can be left 10 to 15 min. it is all the better.

It has been found in practice that two men, one facing the pipe with the pipe-facing machine and the other doing the welding, can complete a weld inside of 10 min. and that it is a simple matter for them to make from 40 to 50 finished pipe welds a day.

It must be understood from the foregoing that the slag that forms on top of the molten material in the crucible is poured into the mold first. As soon as this slag strikes the cold pipe and inner surface of the mold it forms a protective coating which prevents the superheated liquid steel which flows in after it from coming in direct contact with either the pipe or the mold. The heat of the entire mass, however, serves to bring the pipe ends to the desired temperature. The method of pouring will be understood from Fig. 5. In this cut *A* shows the slag flowing into the mold and coating the pipe and inside of the mold; *B* shows the slag in the mold and the steel following, displacing the slag in the bottom part

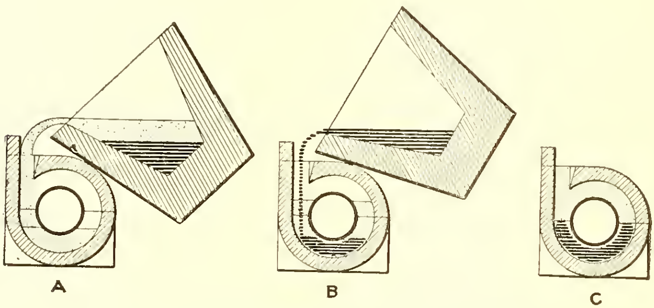


FIG. 5.—Pouring Slag and Steel into the Mold.

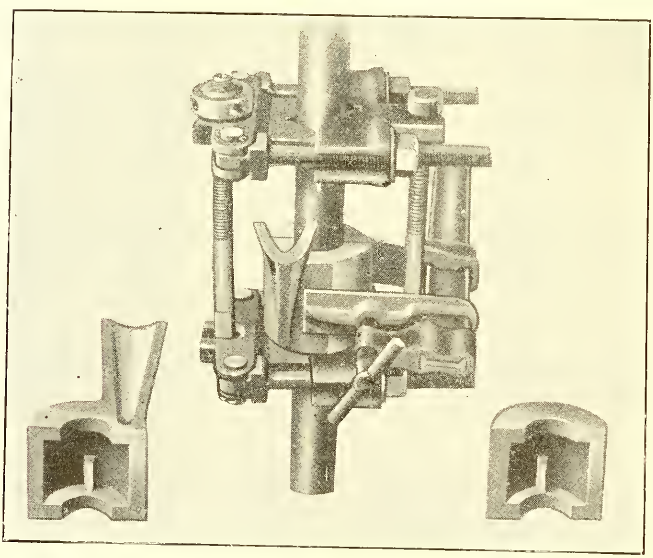


FIG. 6.—Mold for Welding Vertical Pipe.

of the mold, and *C* shows the mold about half full of steel, but a film of slag separating it from the pipe and mold.

The foregoing instructions apply to welding pipe in a horizontal position. Vertical pipe, however, can be welded in essentially the same manner, but a special mold is required. This mold is constructed in such a way as to divide the Thermit-steel collar into two parts, so that it may be readily removed from the pipe on the completion of the weld. The mold also has a different type of pouring gate, as will be seen in Fig. 6.

The same method used for welding pipe may be used for welding bars or rods of mild steel or wrought iron of various sizes and shapes, but this method is not applicable to welding cast iron or high-carbon steel. For the latter work another method must be used.

Cost and Strength of Pipe Welds.—It may be of interest to compare the cost of a Thermit-welded joint with that of mechanically coupled pipe, and for this the reader is referred to Table I, which was taken from "Reactions," which is the house organ of the Metal and Thermit Corporation. While accurate determination of the cost that will cover general practice is always difficult there is no doubt about the superiority from every standpoint of the Thermit-welded joint where a solid, leak-proof and especially strong coupling is wanted. For ammonia-pipe or similar installations the solid joint is one that every real engineer will recommend.

As to the comparative strength of a Thermit-welded pipe joint the following is taken from a report made by Prof. Frederick L. Pryor of Stevens Institute July 10, 1914:

"Two classes of pipe, standard weight and extra heavy, were tested, the sizes selected for each type being 1 in. and 1¼ in. Six samples each of 1-in. standard, 1-in. extra heavy, 1¼-in. standard and 1¼-in. extra heavy were selected for test, three being used for the bursting test and three for the tensile test. One specimen was left in its original form and two specimens were cut in half and joined together, one with a Thermit weld and one with standard-threaded couplings. One specimen of each size and type was subjected to tensile and bursting tests. Standard-weight couplings were used for standard pipe and extra heavy couplings for extra heavy pipe, and the welded specimens were put together by your process. The thickness of the material at the weld was afterward determined and found to be about 0.02 in. more than the thickness of the pipe for the 1-in. specimens, and about 0.075 in. more than the thickness of the pipe for the 1¼-in. specimens. A number of pieces of pipe were measured to check the thickness with the accepted standard and each specimen was within the tolerance factor.

"The tension tests were made in the usual manner, except that a plug was inserted in each end of the pipe in order to assist the gripping action in the machine.

Table I.—Comparative Costs of Mechanical and Thermit Joints, Taken from "Reactions" for the First Quarter of 1918, with Thermit Figured at 35 Cents per Pound.

Size of Pipe, Inches	Average Net Cost Square Arm Flanges with Bolts and Gaskets	Average Net Price Installing and Sweating on Pipe	Total Cost of Installation	Cost of Materials for Thermit Weld	Labor per Joint One Man at 30c per Hour	Total Cost Thermit Weld per Joint
½	$1 01	$0 18	**$1.19**	$0 24	$0 10	**$0.34**
1	1 13	0 18	**1.31**	0 44	0 10	**0.54**
1¼	1 45	0 24	**1.69**	0 65	0 10	**0.75**
1½	1 51	0 30	**1.81**	0 80	0 10	**0.90**
2	1 67	0 42	**2.09**	0 95	0 10	**1.05**
2½	3 15	0 60	**3.75**	1 44	0 125	**1.57**
3	4 16	0 90	**5.06**	2 33	0 15	**2.48**
3½	4 47	1 20	**5.67**	3 06	0 15	**3.21**
4	5 35	1 20	**6.55**	4 60	0 175	**4.78**

The above costs for mechanical joints are based on standard list prices less a 37 per cent. discount.

"The bursting test was made by pumping oil into the pipe under pressure, the actual pressure to force the plug into the cylinder being determined by the dimensions of the pressure plug and the weight on the scale beam.

"In the tension tests all the pipes joined by couplings ruptured in the root of the thread at the coupling, and the welded samples ruptured away from the weld with one exception.

"In the bursting tests all samples, including those put together by couplings and welds, ruptured in the seam of pipe. The location of the ruptures for both the tension and bursting tests are noted in Table II."

Table II.—Results of Tension and Bursting Tests on Screw-Coupled and Thermit-Welded Pipe Joints.

	Dimensions in Inches		
	Outside Diameter	Inside Diameter	Thickness
1″ standard	1.315	1.049	.133
1¼″ standard	1.660	1.380	.140
1″ extra heavy	1.315	.951	.182
1¼″ extra heavy	1.660	1.272	.194

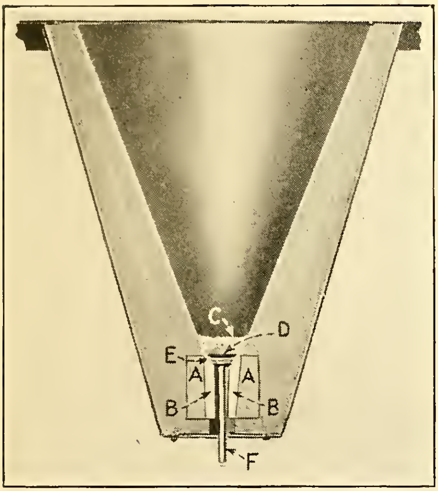
Character of Pipe	Yield Point, (Actual), Lbs.	Ultimate Tensile Strength, (Actual), Lbs.	Approximate Location of Rupture	Bursting Pressure, Lbs. Sq. In.	Approximate Location of Rupture
1″ Standard					
Straight	18,000	**27,900**	Between grips	11,580	Center of pipe
Coupling	17,250	**20,320**	Root of thread at coupling	9,260	6″ from coupling
Welded	16,500	**26,130**	2½″ from weld	10,560	4″ from weld
1″ Extra Heavy					
Straight	19,200	**34,730**	Between grips	13,510	2″ from end of pipe
Coupling	......	**18,770**	Root of thread at coupling	13,310	3″ from end of pipe
Welded	23,000	**34,970**	8″ from weld	14,220	2″ from end of pipe
1¼″ Standard					
Straight	22,300	**37,670**	Between grips	9,440	7″ from end of pipe
Coupling	21,380	**28,500**	Root of thread at coupling	8,050	7″ from end of pipe
Welded	20,930	**36,020**	At weld	8,460	1½″ from end of pipe
1¼″ Extra Heavy					
Straight	29,380	**50,620**	Between grips	12,900	1½″ from end of pipe
Coupling	29,100	**29,100**	Root of thread at coupling	12,770	2″ from end of pipe
Welded	27,800	**50,980**	6″ from weld	11,490	1″ from end of pipe

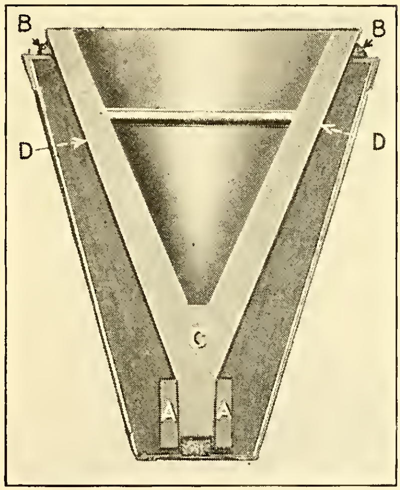
Professor Pryor also at about the same time made some vibratory tests. The pipe selected was 1¼-in. extra heavy, and each test piece was composed of 6-ft. lengths joined together by the coupling or weld. The Thermit welds were made in the presence of Professor Pryor by a representative of the Thermit company and were regular standard Thermit joints. These 12-ft. pieces with a joint in the center were subjected to a vibratory motion, the pipe depressed and raised 2 in. below and above the center line. The test pipe was filled with water under 22 lb. pressure in order to show the first failure of the material. Two tests were made of the pipe joined with extra heavy screwed coupling and one test of the welded joint pipe. The reason only one test was made on the Thermit-welded pipe was that the number of deflections on it was about 250 times the deflections made on the screwed coupling, with no sign of any deleterious effect. Both the screwed-joint specimens broke just outside the coupling in the root of the thread under 6160 and 3430 vibrations respectively. The Thermit specimen was vibrated 1,566,340 times, after which it was removed from the test and at the time no injury was apparent. The speed of these vibrations was about 225 vibrations per minute.

CHAPTER III

FUSION WELDING OF HEAVY SECTIONS

The method of welding heavy sections and castings, or the fusion method, differs considerably from that used for welding pipe joints. For one thing the parts to be welded must be preheated to a red heat and also another type of





FIGS. 7 and 9.—Sectional View of Thermit Automatic Crucible and Method of Lining It

FIG. 7.—*AA*, magnesia stone; *BB*, magnesia thimble; *C*, refractory sand; *D*, metal disk; *E*, asbestos washer; *F*, tapping pin. FIG. 9.—Method of lining a crucible—*AA*, magnesia stone; *BB*, luting of fire clay; *C*, cast iron crucible cone; *D*, layer of wrapping paper or newspaper.

crucible is needed. The type of crucible used is shown in Fig. 7. This is a conical-shaped, sheet-metal receptacle, or shell, with an opening in the lower pointed end. In use this is suspended or supported above the gate of the mold by means of a tripod, bracket or other support. The metal receptacle is lined with magnesia tar, a hard-burnt magnesia stone being set in as shown at *A*. This has a tubular opening in it into which a small magnesia thimble *B* is pressed. This thimble provides a channel through which the liquid Thermit steel is poured into the mold. The object of making the crucible so that it may be tapped from the bottom is to prevent the slag from entering the mold, which is directly opposite to the procedure for welding pipe. The hole in the bottom of the crucible is closed previous to putting in the Thermit mixture by means of the tapping pin *F*, the asbestos washer *E*, the metal disk *D* and the refractory sand *C*. This sand is put up in small bags for the purpose by the company selling the mixture. When everything is ready the Thermit is put into

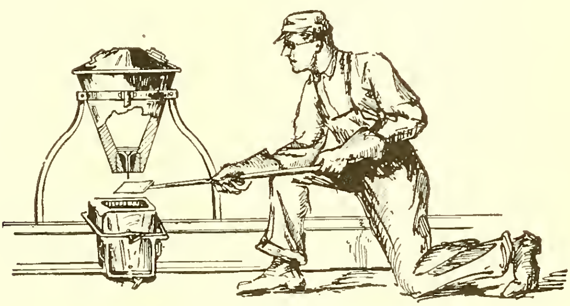


FIG. 8.—Tapping a Crucible.

the crucible and ignited exactly as described for pipe welding. After the reaction the tapping pin is pushed up as shown in Fig. 8 and the molten steel allowed to run out into the mold.

The crucible and the thimble through which the metal runs after the reaction are two of the most important factors in the whole process. The high temperature, together with the violent ebullition of the molten metal during the reaction, necessitates a lining that is not only mechanically strong but of a very high refractory substance. It has been found that magnesia-lined crucibles are the only ones that satisfy these conditions.

Life of Lining Prolonged by Patching With Magnesia Tar.—As refractory as this material is, however, the crucibles that are used to any extent must be relined. Sometimes the life of a lining may be prolonged by patching with magnesia tar where needed and then baking it. While any good mechanic can scheme out ways to line a crucible in an emergency and may use fire clay on occasion the following method is given as the best way:

The magnesia-tar lining material should be heated until it becomes plastic. A few handfuls are then placed in the bottom of the crucible shell and a magnesia stone imbedded in this material, as shown in Fig. 9, and centered over the hole. More magnesia tar is then rammed around the stone to hold it firmly in place. The cast-iron crucible cone should then be placed in position with the small projection set into the hole in the magnesia stone. The upper part is next centered in the shell by means of wedges inserted at equal distances along the circumference. The magnesia tar is then rammed into the space between the cone and the shell a little at a time and tamped hard. On the density or hardness of the lining depends the life of the crucible. Special iron tamping tools with flat ends should be used. The rammer should be pounded well with a good-sized hammer when ramming in the lining. Better still is a pneumatic bench rammer.

Do not put in the material too rapidly, and let it be remembered that the better and more uniform the tamping the longer the crucible will last.

As the mass nears the top the wooden wedges should be removed as the lining already in place will hold the cone in position.

The Crucible Ready for Baking.—When completely filled and tamped a mark should be made with a piece of chalk on the cone and the point opposite to it on the lining, so that when the cone is withdrawn it may be replaced exactly as before. Then take the cone out, exercising care not to disturb the lining, place a layer of wrapping paper or newspaper over the tar lining, then replace the cone carefully, so that the marks previously made come opposite to each other. After this put on the crucible ring and lute carefully around the top with fire clay to protect the upper part of the lining from the heat in baking. It is also well to place damp fire clay around the bottom of the crucible and inside of the stone for the same purpose.

The crucible is now ready for baking, and for this purpose it should be placed in a suitable oven. The heat should gradually be raised until the cast-iron cone becomes red hot and should be held at that temperature until all the fumes stop coming off from the tar, after which it can be allowed to cool gradually before removing from the oven. If the crucible is baked too long the lining will appear crumbly and the life of the crucible will be very much shortened. Baking for too short a time will leave some of the tar in the lining and cause a violent Thermit reaction. When cool the clay luting may be removed, the cone taken out and the crucible is ready for use.

Thimbles.—The portion that has to withstand the most severe strain of all is the part at the bottom of the crucible, or walls of the hole through which the metal is tapped. It has to stand the wash and pressure of the weight of the moving liquid metal and slag under great heat.

The magnesia stone which is centered in the bottom of the crucible and around which the material for lining is packed has a tapered hole in the center. The thimbles are of the same taper as the hole in the magnesia stone and are set into the latter. When the thimble is used up (either through enlargement of hole or by splitting) it can be knocked out and replaced with a new one, so that the full life of the crucible may be utilized. Thimbles should be wrapped with one layer of uncreased paper before being placed in position.

Since various amounts of Thermit must be used for different sized welds the crucibles used must vary accordingly, although it is possible on occasion to use more than one crucible at a time for a given melt. This is not advisable, however, unless necessary. For lining these various sized crucibles the Thermit company makes magnesia stones and thimbles in certain sizes designated by numbers. The metal cones as well as crucibles of a given capacity are also numbered. All of the ordinary sizes, as well as the amount of magnesia tar needed, are shown in Table III.

The Care of Crucibles.—We have described in detail the construction of automatic crucibles to be used in connection with Thermit welding, and it might be well to include a few words on the proper care of these crucibles.

They should be very carefully handled, as the lining is

TABLE III.—DETAILS OF AUTOMATIC CRUCIBLES, LINING MATERIALS, CONES, STONES AND THIMBLES.

Size of Crucible	Capacity in Pounds of R. R. Thermit	Gross Shipping Weight of Crucibles Pounds	Outside Diameter at Top, Inches	Height, Inches	Size of Magnesia Stone for Relining	Size of Magnesia Thimble to be Used	Size of Plugging Material to be Used	Weight of Magnesia Tar Required for Relining, Pounds	Size of Crucible Cone Corresponding to Size of Crucible	Shipping Weight of Cones, Pounds
No. 1	6	40	8½	8½	No. 1	No. 1	No. 2	8	No. 1	50
No. 2	8	60	10	10	No. 1	No. 1	No. 2	20½	No. 2	50
No. 3	15	110	12½	13½	No. 2	No. 2	No. 2	42	No. 3	75
No. 4	25	125	14½	15	No. 2	No. 2	No. 2	61½	No. 4	125
No. 5	35	150	16½	15	No. 2	No. 2	No. 2	87	No. 5	150
No. 6	70	250	20	21	No. 2	No. 2	No. 2	141	No. 6	225
No. 7	140	450	25½	25	Nos. 1 and 2	No. 2	No. 2	216	No. 7	375
No. 8	210	525	28	28	Nos. 1 and 2	No. 2	No. 2	258	No. 8	375
No. 9	280	650	30½	29½	No. 3 and 3 Spec.	No. 3	No. 3	327	No. 9	600
No. 10	400	775	34	34	No. 3 and 3 Spec.	No. 3	No. 3	408	No. 10	600

NOTE.—Four magnesia thimbles and five packages of plugging material are supplied with each new crucible.

apt to crack or fall out under rough treatment. It is also always important that they be stored in a dry place, as the lining, being porous, will absorb moisture, and a moist lining will cause violent Thermit reaction.

After a crucible has once been used, it is not necessary to clean it of the slag adhering to the inside, as this is a very refractory material itself and can do nothing but help preserve the crucible if left on. At the bottom, however, in the vicinity of the stone and thimble, the slag has to be removed so as to clear the opening of the thimble or permit of an old thimble being knocked out and a new thimble inserted.

Applications of Fusion Welding.—With the construction and method of using the automatic crucible in mind we will

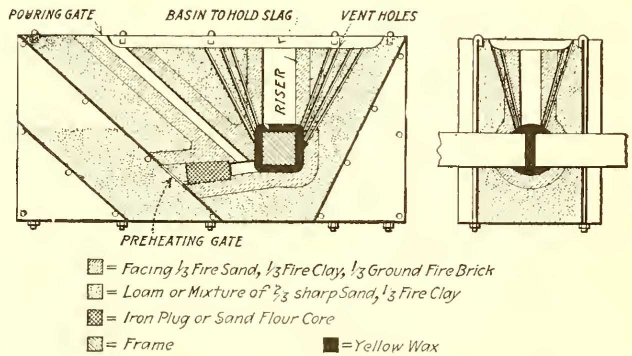


FIG. 10.—Typical Thermit Mold for Heavy Sections.

next take up the welding of heavy or solid sections in detail. In order to make this clear a typical Thermit mold is shown in Fig. 10. With this illustration to refer to the following directions will be readily understood:

We will suppose that the parts to be welded are those of a broken frame. It is best to put tram marks on the two sections far enough back from the fracture to be outside the mold box when it is in place. These are convenient to measure from when allowing for the contraction of the Thermit steel as it cools. Next cut along the lines of the fracture so that an opening of from 1 to $1\frac{1}{2}$ in. is provided. The amount of the opening depends on the size of the sections to be welded, but in no case should it be less than an inch. If it is a diagonal fracture it is usually best to cut it so as to make as near a vertical opening as possible.

There are various ways of cutting away the metal for the opening, such as sawing, drilling and chiseling, but the best way is to use an acetylene and oxygen cutting torch. In any case the opening should be clear enough to allow the free flow of the Thermit. Now clean the ends of the sections thoroughly for at least four inches from the opening, so as to expose the good, bright metal. Be sure to remove all dirt or grease as far back as the mold box will reach, so that when the mold is rammed up and heat applied there will be no grease to burn out and leave a space between the mold and part to be welded.

If the oxy-acetylene torch is used for cutting be sure to remove all oxide or scale left on the parts by the operation. Next make allowance for contraction by setting the parts away from each other a sufficient amount to make up for the contraction of the Thermit steel and adjacent parts in cooling. This should be varied from $\frac{1}{8}$ in. to $\frac{1}{4}$ in., depending on the size of the weld. In many cases it is necessary to obtain this increased space by forcing the sections apart with a jack or other mechanical means. In other cases, such as the welding of a double-barred locomotive frame, it will be necessary to heat an opposite member by means of a flaming burner attachment on a double-burner preheater or by using a basket fire. It is sometimes advisable to construct a small fire-brick or sheet-iron furnace around such a section in order to confine the heat or protect other parts from the flame. This, however, is done only at the time of preheating.

With the parts lined up and proper allowance made for contraction they are ready for the wax mold.

Wax-Pattern Molds.—The wax-pattern molds are made of yellow wax, as indicated in the illustration of a typical mold. This wax is placed in a pan and warmed until it becomes plastic or else melted entirely and then allowed to cool until plastic. This wax is then shaped around the parts to be welded in the form of a collar as shown. The opening between the ends should also be filled with wax, and it is necessary to provide a vent hole through the wax extending from the location of the heating gate to the riser. The best way to do this is to imbed a piece of good stout twine in the wax, which can be pulled out after the pattern is formed.

The mold box, details of which are shown in Fig. 11, should then be placed in position and securely blocked up so that all weight will be removed from the sections to be welded.

We are now ready for the molding material. This should consist of one part fire clay, one part ground fire brick and one part fire sand. This is used for the facing of the mold or the part that comes in contact with the Thermit steel. If

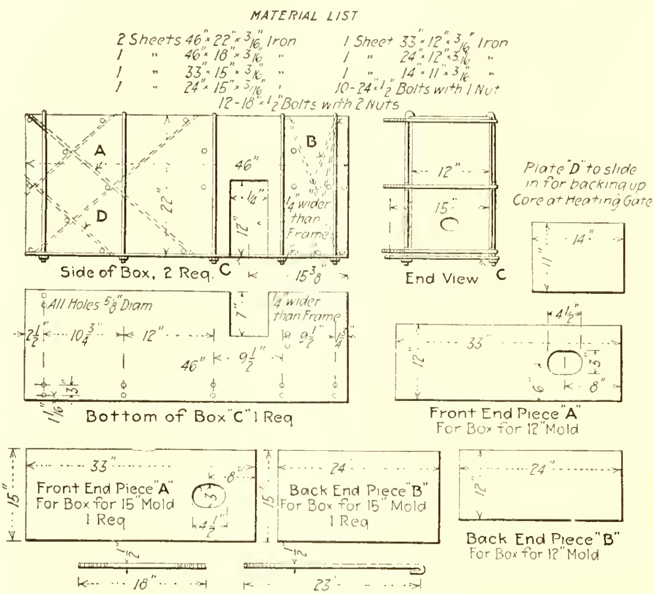


FIG. 11.—Design and Materials Required for Standard Mold Box.

it cannot be obtained in the vicinity it can be ordered from the Thermit company. This material should be well riddled, mixed dry and then moistened with just enough water so that it will pack well.

Ramming the Mold.—In ramming up the mold place a small amount of molding material in the box and ram with a small rammer around the edges and working toward the center, keeping the mold level, and *ram hard*. Too much emphasis cannot be laid on this point, for in the construction of the mold depends the safety of the entire welding operation. See to it that the material is well rammed underneath the pattern. There should be a wall of molding material at least 4 in. thick between the wax pattern and the mold box at all points, as the Thermit steel is intensely hot and ample material must be provided to hold it. A wooden gate pattern for the preheating opening should be set at the lowest point of the wax pattern and leading out to the front of the mold box, where an opening is provided for it. Where the sections to be welded together are of the same size this preheating gate should be set directly in the middle of the lowest part of the wax pattern so as to heat both sides of the frame equally. Sometimes,

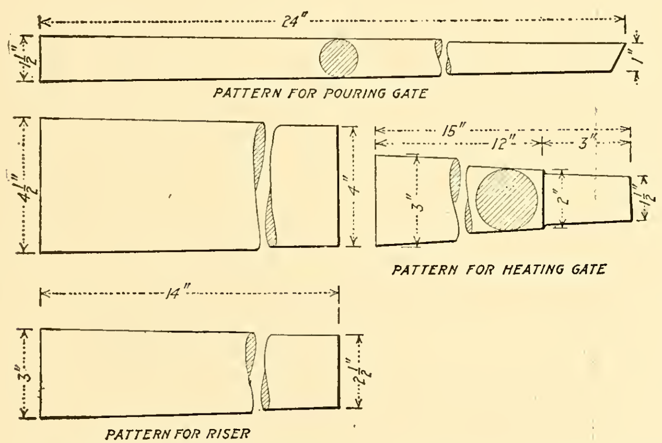


Fig. 12.—Wooden Patterns for Pouring Gate, Riser and Heating Gate of Mold. These Are Large Enough for Welds Up to 5 × 7 In. Larger Welds Require Proportionately Larger Patterns.

however, it is necessary to weld a light frame section to a heavier one, in which case the preheating opening should favor the heavier section, which will require a longer time to heat than the light section.

With the preheating gate provided for, set another wooden gate pattern directly above it and one inch away from the wax pattern and have it properly shaped for the pouring gate. Drawings for these various patterns are shown in Fig. 12.

Be sure that the molding material is well rammed around these patterns so that it will not "cut out" under the blast of the preheater.

At the highest point of the wax pattern place the riser pattern. If there is more than one high point, place a riser pattern over each, as the function of a riser is to hold a supply of steel which will remain liquid for a considerable period of time, and take care of all shrinkage, so that when a "pipe" is formed, due to shrinkage, this pipe will appear in the riser and not in the weld. Also the riser acts as a depository for loose sand or other foreign matter that may be washed into

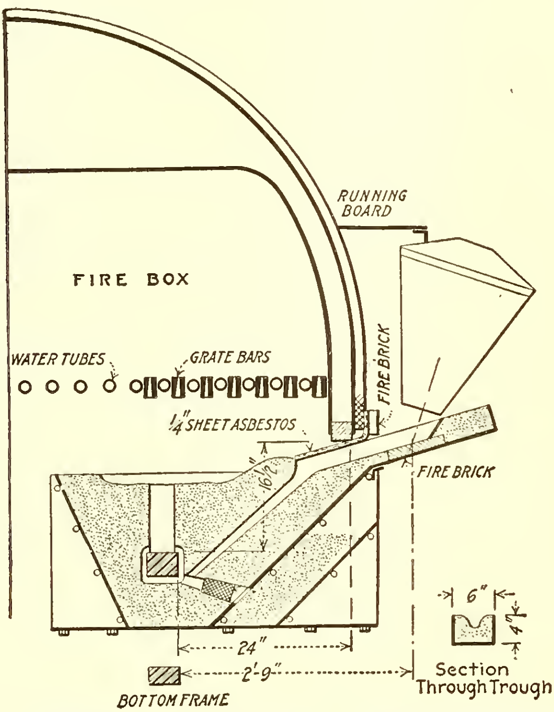


Fig. 13.—Method Employed in Making Welds in Inaccessible Places.

it by the Thermit steel in passing through the mold and prevents this material from clogging in the weld. It sometimes happens that welds are made at a point where a wooden riser pattern cannot be withdrawn conveniently. In such cases a piece of jacket-iron pipe may be used and left in the mold after ramming up. The Thermit steel will flow into this opening and simply melt the iron pipe and amalgamate with it.

After the mold is all rammed up, hollow out on top so as to form a basin in which the slag may collect so as not to overrun the mold box. Then vent the mold thoroughly by making holes with a vent rod made from 8 to 10 gage steel wire, so that all gases in the liquid metal will have a chance to escape, as shown in the typical mold. This is important.

Now lightly rap the gate, riser and preheating opening patterns and draw them out carefully, wiping away any loose sand that might tend to fall into the holes. A molder's slick, trowel and lifter are very useful in this connection. Then cover the various openings so that nothing will fall into them and adjust the crucible in position with the bottom about 3 in. above and directly over the center of the pouring gate. Where this cannot be done, construct a runner, as shown in Fig. 13, to lead the steel into the pouring gate of the mold.

Preheating the Mold.—The mold is now ready for preheating. Set the burner of the preheater so as to point into the heating gate of the mold and about 1 in. from the opening; then apply the blast. It is best to start easily at first, as too much of a blast would tend to "cut" the mold. The wax will burn out, leaving a perfect mold the shape of the wax pattern. Keep the heat going until the mold is thoroughly dried out and the parts to be welded are brought up to a good, red, workable heat such as would be required if the frame was to be hammered.

While the preheating is in progress the charge of Thermit and additions should be placed in the crucible, which is first plugged in accordance with the directions previously given. It is important to put in a few handfuls of Thermit first before dumping in the rest of the charge, so as not to disturb the plugging material. Mix the Thermit charge thoroughly before putting in the crucible. No ignition powder should be added until the Thermit charge is ready to be ignited. If the Thermit charge when leveled off comes closer than 2 in. to the top of the crucible or if the crucible has to be tipped slightly it is best to build up the crucible by means of a ring. This ring should be less in diameter than top of crucible so it can set in the crucible about 1 in. It should be from 8 to 10 in. high and made from $\frac{1}{4}$-in. stock. Lute with fire clay between ring and crucible.

When it is assured that the frame is at a good workable heat quickly remove the preheater and direct it down the riser so as to blow out any sand or dirt that may be in the mold. If the riser is difficult of access direct the burner down the pouring gate. Then plug the preheating hole with a piece of fire brick ground to fit or an iron plug inserted as shown in Fig. 10. Back this up with several shovelfuls of molding material between the mold box and steel plate provided for the purpose and then pack the sand down hard with a rammer. This will prevent any possibility of the Thermit steel running out through the preheating opening. All heating apparatus should be removed to a safe distance while the Thermit reaction is in progress.

IGNITING THE THERMIT

Place one-half teaspoonful of ignition powder on top of the Thermit in the crucible (Thermit will not ignite from the heat of the preheater and the reaction cannot be started without ignition powder). Ignite this with a parlor match, applying the same immediately after striking, or else ignite with a red-hot iron; this often is the easier method. It is important that ample time be allowed for the completion of the reaction and for the entire fusion of the punchings, which are mixed with the Thermit. It is best to wait at least 35 sec. before tapping the crucible. This is accomplished by knocking up the tapping pin which sets in the bottom of the crucible, using for the purpose the tapping spade or a flat piece of iron $1\frac{1}{2}\times\frac{1}{4}$ in. by 4 ft.

Hold up the expansion on the parts with a jack or preheater until the metal in the weld has set and shrinkage commences to set in; then remove the jack or shut off the heat. This should be usually done about two or three hours after the weld is made, but depends largely on the size of the section and length of preheating.

The mold should be allowed to remain in place as long as possible, preferably over night, so as to anneal the steel in the weld. In no case should it be disturbed for at least six hours after pouring.

After removing the mold, drill through the metal left in the riser and pouring gate and knock these sections off, or else cut them off with an oxy-acetylene torch.

Amount of Thermit Needed for Welds.—The amount of Thermit needed for welding sections of different sizes can be derived from Table IV, which contains the proper proportions of manganese, nickel and punchings. These amounts are given on the supposition that the Thermit collar or reinforcement is made in accordance with the dimensions published in the table.

TABLE IV.—WELDING PORTIONS FOR WELDING RECTANGULAR SECTIONS.

Width of Section Inches	Depth of Section Inches	Width of Thermit Steel Collar Inches	Thickness of Thermit Steel Collar at Center Inches	Quantity of Railroad Thermit Required for Weld Pounds
3	2	4	1	40
3	2½	4	1	40
3	3	4	1	45
3	3½	4	1	50
3	4	4	1	55
4	4	4	1	65
4	4½	4	1	65
4	5	4	1	70
4	5½	5	1¼	75
4	6	5	1¼	75
4½	4½	5	1¼	70
4½	5	5	1¼	75
4½	5½	5	1¼	75
4½	6	5	1¼	80
5	5	5	1¼	75
5	5½	5	1¼	80
5	6	6	1½	85
5	7	6	1½	90
5½	5½	6	1½	85
5½	6	6	1½	90
5½	7	6	1½	110
6	6	6	1½	100
6	6½	6	1½	120
6	7	7	1⅝	130
6½	6½	7	1⅝	130
6½	7	7	1⅝	150
6½	8	7	1⅝	160
7	7	7	1⅝	155

It is better practice, however, to calculate the amount of Thermit needed for a weld from the weight of wax used in the pattern and it is advisable anyway to make this calculation as a check.

Where the quantity of Thermit is calculated from the wax great care should be taken to see that the entire space which is to be filled with Thermit steel is filled with wax so that not only the collar but the space between the sections is filled with wax. Then, by weighing the wax before and after the completion of this operation, the difference will be the quantity of wax used, and this weight in pounds multiplied by 30 will give the proper amount of railroad Thermit for the weld.

It is recommended that railroad Thermit be used in all cases, as it is ready mixed with 1 per cent pure manganese, $\frac{5}{8}$ per cent nickel shot and 15 per cent mild-steel punchings. This has been found to give the best results for welding wrought iron and steel. For convenience railroad Thermit is supplied in waterproof paper bags holding $29\frac{1}{4}$ lb. of the mixture, so that one bag to the pound of wax is sufficient for a weld. This rule provides ample Thermit steel not only for the weld proper, but also for the pouring gate and riser.

In case the user has only plain Thermit on hand he should then allow 25 lb. of plain Thermit to the pound of wax, and should mix with this amount of plain Thermit 1 per cent pure manganese, $\frac{5}{8}$ per cent nickel shot and 15 per cent mild-steel punchings. In other words, to every 100 lb. of plain Thermit add 1 lb. pure manganese, 10 oz. nickel shot and 15 lb. mild-steel punchings. These punchings must be clean and free from grease or dirt of any kind and not more than $\frac{3}{8}$ in. in diameter by $\frac{1}{8}$ in. thick.

These rules apply only to welds requiring less than 300 lb. of Thermit. For welds requiring more than 300 lb. of Thermit the usual mixture takes 20 per cent mild-steel punchings with the other additions the same. If railroad Thermit is used add $3\frac{3}{4}$ lb. of punchings to each bag. In special cases it is sometimes advisable to make up a special mixture in order to produce a Thermit steel of essentially the same analysis as the steel in the parts to be welded. Where the amount of Thermit calculated comes to ten bags or more, one of these bags may be dispensed with; that is, instead of using ten bags use nine, or instead of using 20 bags use 18, and so on, as the smaller percentage of metal required for gates and risers makes it unnecessary to use so much of the mixed Thermit.

Where it is desired to calculate in advance the amount of Thermit required for a weld it is first necessary to estimate the number of cubic inches in the space to be filled with Thermit steel, i.e., the space between the ends of the sections to be welded together and the cubical contents of the Thermit-steel collar or reinforcement fused around the weld. Allow $\frac{3}{4}$ lb.

of railroad Thermit to the cubic inch, and this will be sufficient not only for the weld proper but will provide ample metal for pouring gate and riser. In estimating the cubical contents of the collar the simplest method is to multiply the width by the greatest thickness (i.e., the thickness at the middle part); then multiply this product by 0.7. This will give the average area of the cross-section of the collar. If this is then multiplied by the total length of the collar around the outside of the frame and if all measurements are taken in inches the result will be the number of cubic inches in the collar.

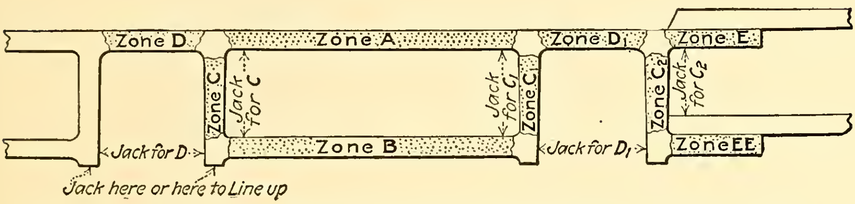


FIG. 14.—Method of Preventing Unequal Stresses When Welding Locomotive Frames Broken at Various Points.

Fracture Location	Remarks
Zone A*..............	Heat zone B to get 3/16 in. expansion and hold 2 to 3 hours after welding. Preheater or basket fire.*
Zone B*..............	Heat zone A to get 3/16 in. expansion and hold 2 to 3 hours after welding. Preheater or basket fire.*
Zone C, C_1 or C_2........	Jack 3/16 in. at C, C_1 or C_2; keep jack in place 2 to 3 hours after welding and then remove entirely.
Zone D or D_1..........	Jack 3/16 in. at D or D_1; keep jack in place 2 to 3 hours after welding and then remove entirely.
Zone E...............	Cut out unfractured member of splice to clear collar.

* When heating either Zone A or Zone B the adjacent pedestal brace or braces should be put in place before commencing to heat so as to distribute the expansion and not upset or distort the leg.

Locomotive Frame Work.—The foregoing directions refer to the general run of wrought-iron or steel repairs, but with only slight variations the same method is followed for locomotive-frame work. The principal difference is in placing the mold or allowing for contraction in various members and not in the use of the Thermit itself. In order to make it clear where stresses are liable to be set up in a locomotive frame the diagram shown in Fig. 14 has been made. By a careful study of this and the application of the principles illustrated a welder should be able to figure out his work so as to produce satisfactory results.

The illustrations will be of assistance in planning the work on various parts of a locomotive frame. Fig. 15 shows how to place the mold and jacks for welding a broken frame leg. With the pouring gate and risers as indicated they permit of

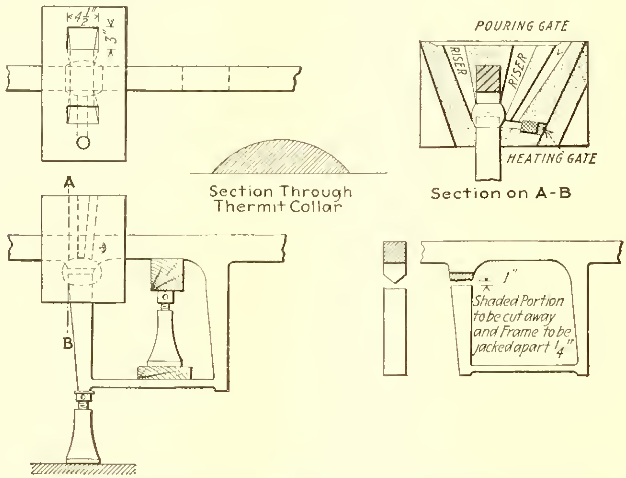


Fig. 15.—Method Employed in Welding Locomotive Frame Broken in Leg.

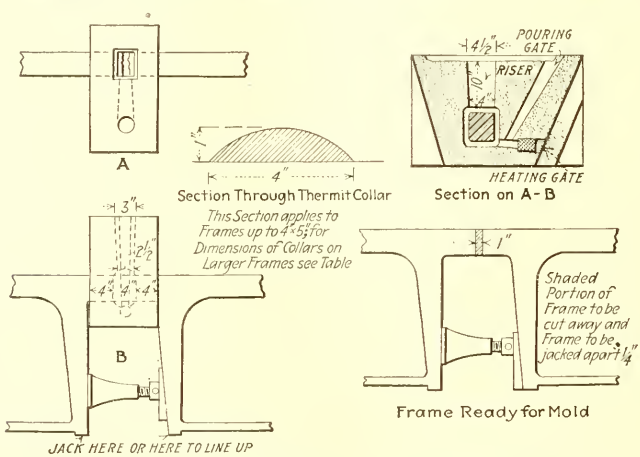


Fig. 16.—Method Employed in Welding Locomotive Frame Broken in Jaw.

a good washing action for the Thermit steel, so that any slag or sand that might be in the mold will be carried into the risers.

Fig. 16 shows how to weld a frame broken in the jaw.

Fig. 17 shows how to weld a frame broken in the splice. In this it is best in making the repair not only to weld the broken sections together, but also to cut out a piece about 1×5 in. of the unbroken member, so the Thermit will flow entirely around the broken sections. By making the repair in this manner a good, strong job is assured, and if the bolt hole is welded up and the two members welded together future breakage at these particular points is practically eliminated.

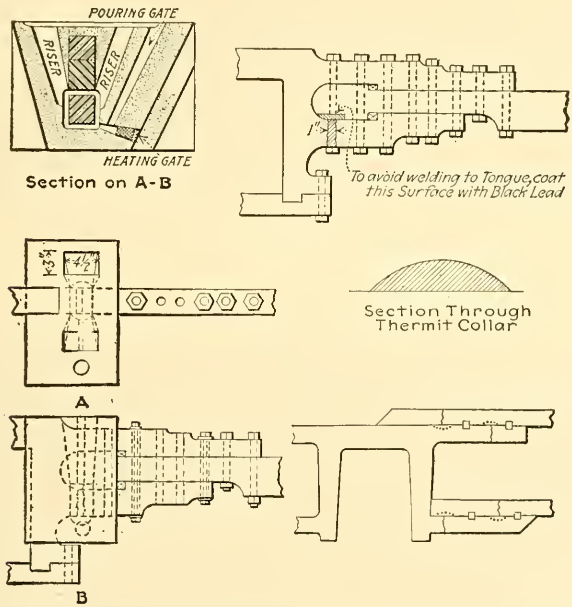


Fig. 17.—Method of Welding Frames Broken in Splice. Lower Drawing Shows How to Drill and Cut the Unbroken Member.

The only objection that can be raised against this practice is the trouble of separating the members in case the splice is to be removed or in order to take out or renew a cylinder. This objection, however, is not serious because it is only necessary to drill a line of small holes where the parts are welded together and the member can then be removed. When replacing it is best to cut a keyway where the frame is cut out and then bolt together in the same way as when the frames were originally assembled.

Fig. 18 shows how to weld locomotive mud rings without cutting the sheets. This method has proved entirely satisfac-

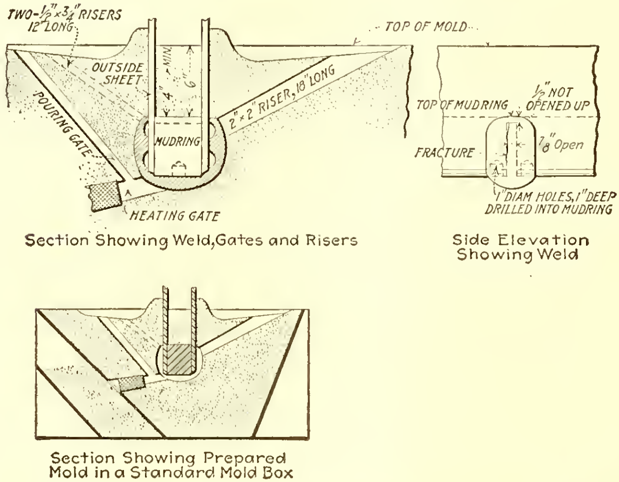


FIG. 18.—Mold for Welding Mud Rings Without Cutting Sheets.

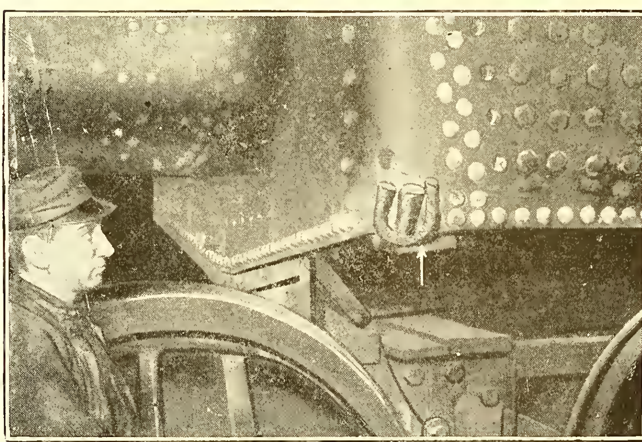


FIG. 19.—Thermit Weld on Mud Ring.

tory and many such welds have been completed and are giving good service.

Typical Welds.—Fig. 19 is that of a finished mud-ring weld, in which the sheets are not cut.

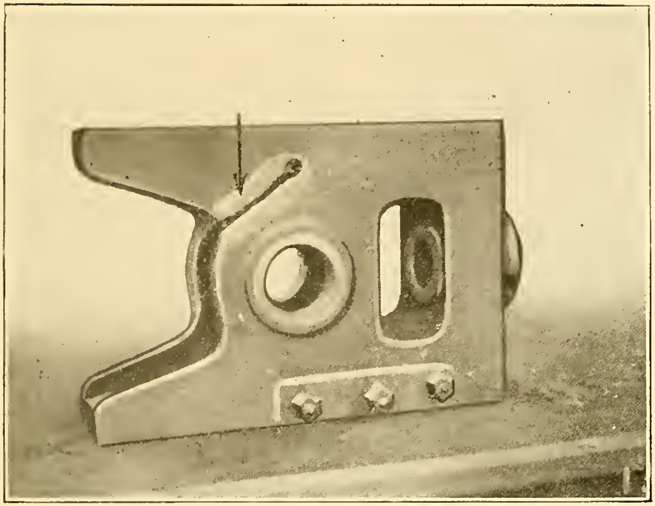


FIG. 20.—Fracture in Crosshead Cut Out for Welding.

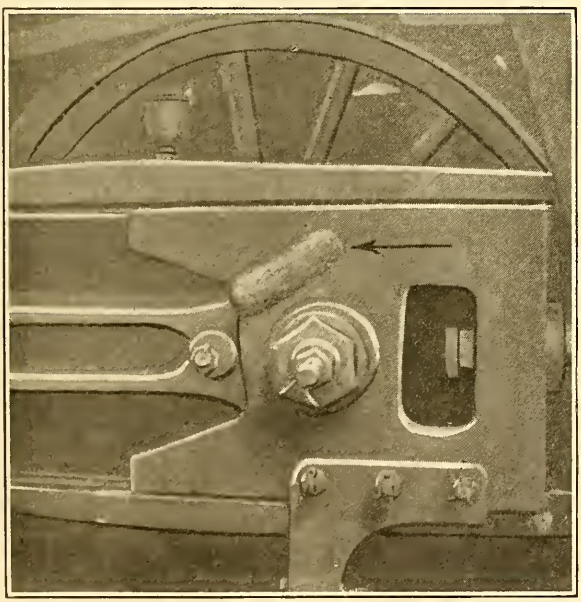


FIG. 21.—Weld Completed and Crosshead in Service.

Fig. 20 shows a fracture in a crosshead cut out for welding. Fig. 21 shows the weld completed and the part in service.

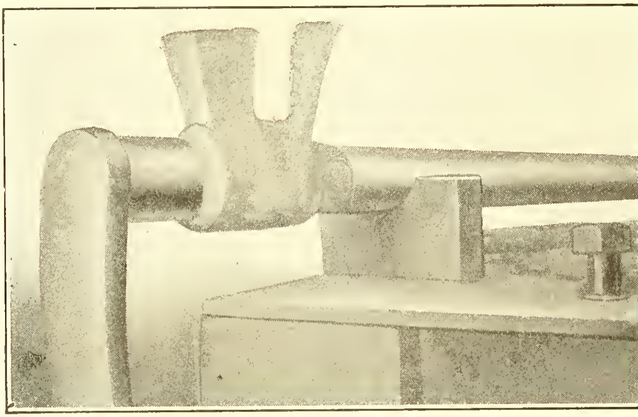


FIG. 22.—Weld on Broken Rocker Shaft Before Machining

Fig. 22 shows a weld on a broken locomotive rocker shaft before machining.

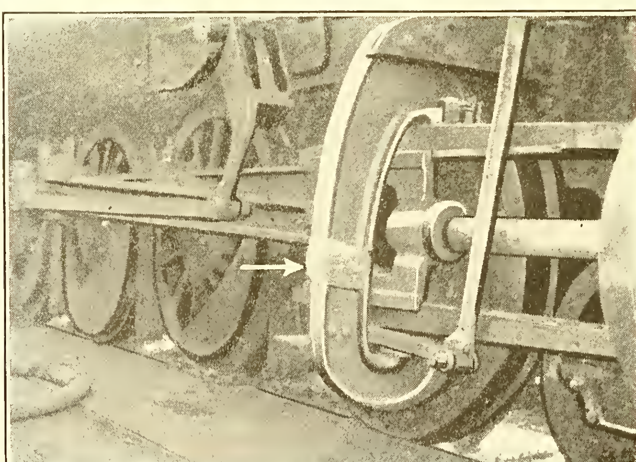


FIG. 23.—Repair on Broken Guide Yoke.

Fig. 23 shows a repair on a broken guide yoke.
Fig. 24 illustrates two welds in an engine splice.

Fig. 25 is a repaired driving-wheel center.

Fig. 26 shows details of a crucible holder for frame welds.

No attempt has been made to make the list of repairs on locomotive parts complete, but enough has been shown to serve as a guide for practically everything that is apt to confront

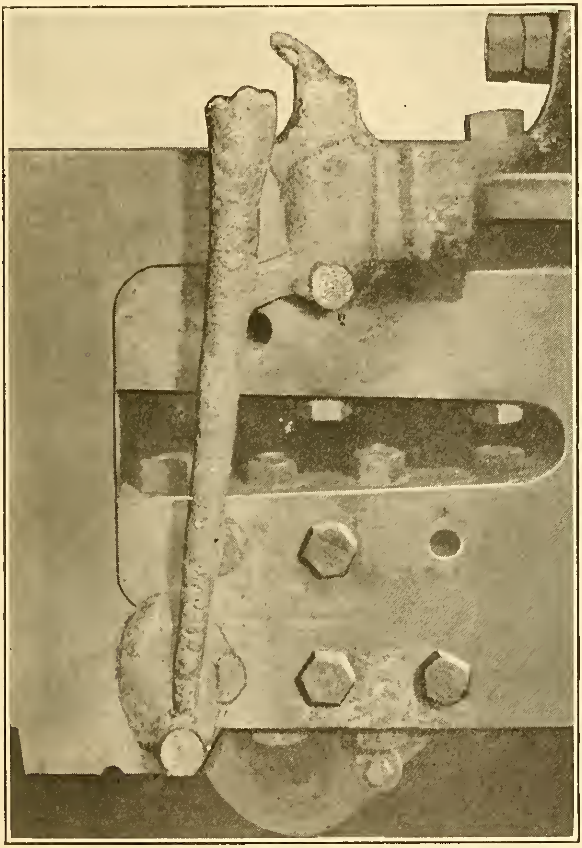


FIG. 24.—Two Welds in Splice of Frame.

the practical man. For superheater work, or pipe work of any kind, the directions given under the heading of pipe welding will cover all that is necessary.

As a sort of recapitulation of the foregoing directions, it will be well to keep the following "don'ts" in mind when getting ready for all locomotive Thermit-welding work.

Don't keep your material and appliances in a damp place. Better store them all in a good, dry room under lock and key, the foreman in charge of the Thermit work to have the key. Better still construct a tool wagon and keep all Thermit material in it.

Don't start to make a Thermit weld unless you have all the necessary materials and appliances and the latter in good condition.

Don't neglect to clean the frame thoroughly. Be sure to

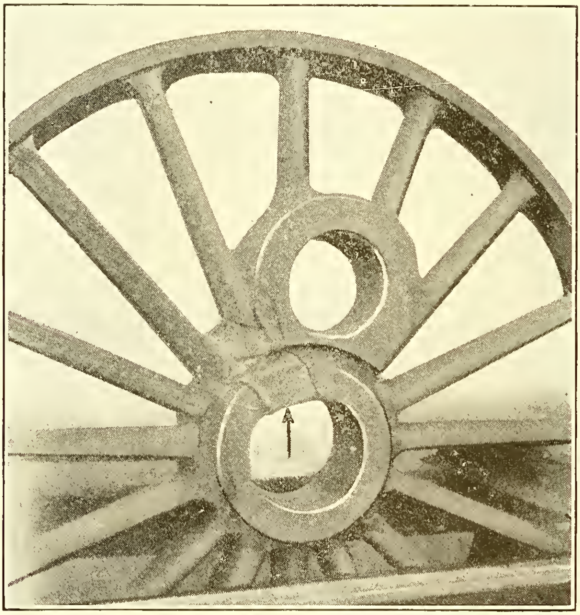


FIG. 25.—Weld on Driving-Wheel Center.

remove all the grease, paint, etc., and have as good clean metal as possible to work on.

Don't neglect to take care of the contraction that is bound to be set up as the metal in the weld cools. If this cannot be allowed for by spreading the sections with a jack or other mechanical means heat the opposite unbroken member with the other burner of a double-burner preheater fitted with a flaming-burner attachment. If this is not available hang a basket fire of charcoal or coke about the unbroken member and heat until proper expansion is obtained, holding up the heat for two or three hours after the weld is poured. It is advisable to expand the frame $^3/_{16}$ in. on the average. Cut out the frame along the fracture so as to make a clean opening 1 in. wide. Proportion your wax pattern to the size of the frames as shown in the table.

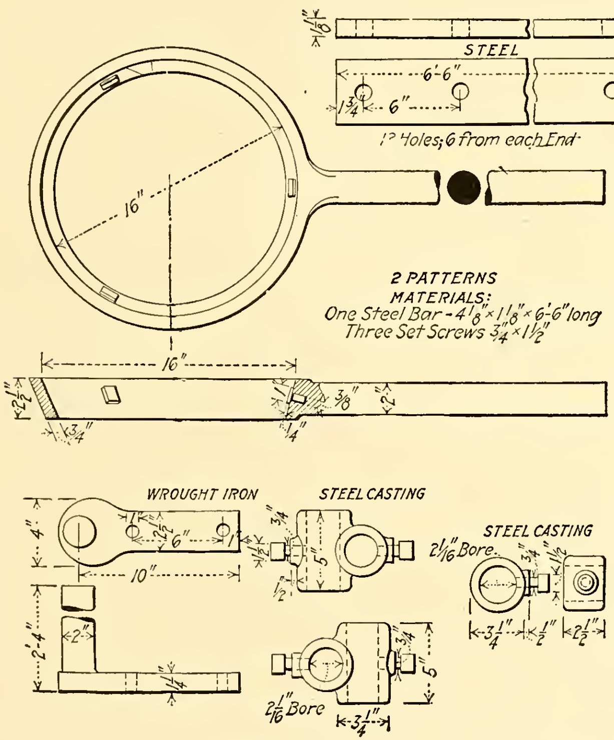


FIG. 26.—Design for Crucible Holder for Locomotive-Frame Welds.

Don't use pin grease or wood in place of wax for the collar. Pin grease has some sulphur in it and we all know how undesirable the presence of sulphur is in iron or steel. Pin grease and wood of course burn out in the preheating, but they leave a carbon deposit that will not burn off but will bake on.

Don't vary the dimensions of the wax collar. Make collars of uniform width and thickness on all sides, thus insuring an even distribution of heat. In the case of welds on pedestal legs cutting down the thickness of the collar is poor policy. Remember that the weld is the object and the weld will not be perfect if the dimensions of the collar are not the same on all sides.

Don't moisten the molding material too much. Have it damp enough to bind under the natural pressure exerted in closing the hand.

Don't use a molding material that runs to slag in the course of preheating; if it will not stand the preheating torch it surely will break down to slag, as the Thermit steel flows into it, and a mixture of slag and steel is not at all desirable and furthest from a perfect weld.

Don't forget to support the frame and mold box by means of blocks or jacks, as the weight of the rammed mold is considerable and will sag the frame.

Don't start off the preheater with too strong a blast. Take it easy at the start and increase the air and gasoline as the moisture is driven out of the molding material. In this way the mold will not be cut out and a clean-looking job will be the result, with no lumps.

Don't pour the Thermit on a black-hot frame; heat it to a good workable heat.

Don't use crude or fuel oil to preheat the frames. In starting the burner of a heater using either, carbon is deposited on the frame and prevents a good weld. Heat preferably with gasoline and compressed air. If gasoline is forbidden use kerosene, but under no circumstances use crude oil or fuel oil.

Don't be careless in plugging the crucible. Careless plugging results in premature tapping, and this latter might lead to ugly looking or defective welds due to the imperfect separation of slag and steel.

Don't guess how much Thermit to use. Consult the table of instructions and you will not go astray.

Don't use anything but railroad Thermit for welding a steel or wrought-iron section. For cast-iron sections use cast-iron Thermit.

Don't add the ignition powder to the charge in the crucible until ready to start the reaction. It is advisable to suspend the crucible in place, charged with Thermit, before starting to preheat. Everything will then be ready for pouring at the proper time.

Don't tap the crucible too soon after starting the reaction. On an ordinary frame weld taking from 65 to 100 lb. of Thermit permit 35 to 40 sec. to elapse between starting the reaction and tapping the crucible. This to insure good separation of steel and slag.

Don't release the spreading bar or jack or take off heat too quickly after pouring. It is best to hold up the expansion for two to three hours before removing jack or shutting off heat.

Don't remove the mold box too quickly after the pour. Let it remain in place over night; it will insure the frame cooling off slowly and naturally.

Don't forget to gather up all the materials and appliances after completing the work. Take them to the room that you ought to have for the storage of this material and it will be at hand when you want to make use of it again.

Don't get excited—keep cool.

Don't take a chance. Be sure everything is right as you go along. There is no such thing as luck.

Also remember that the riser must be $2\frac{1}{2} \times 4$ in. at the bottom and $3 \times 4\frac{1}{2}$ in. at the top and not less than 14 in. high where clearances will admit. In the case of welds on vertical members two risers should be used, but their total capacity need not be greater than the riser for which dimensions have been given. The pouring gate must be not less than 1 in. in diameter at the bottom, $1\frac{1}{2}$ in. in diameter at the top and 30 in. long. Mold boxes should be made of $^3/_{16}$-in. sheet iron, allowing for at least 4 in. of molding material on all sides of the Thermit steel.

CHAPTER IV

WELDING CRANKSHAFTS, MILL PINION TEETH, ETC.

We will now take up the welding of crankshafts, mill pinions, rudder-stocks and other repairs which must be lined up as accurately as possible. It is not necessary to go into details as to the exact method of making the Thermit welds, as these have already been thoroughly covered. It is merely intended to go into the question of allowances for contraction, causes of inaccuracies in alignment after welding, effects of mechanically preventing the expansion and contraction and other possible difficulties.

Mechanically preventing the contraction of a weld, intentionally or otherwise, is a common fault in Thermit welding and can be prevented only by constant vigilance on the part of the operator. Most operators in repairing locomotive frames, for instance, will arrange to jack the sections of the frame apart or separate them by heating the adjacent members or in some similar way to allow for the contraction which they know will take place when the metal in the weld cools. When, however, the Thermit operator is confronted with the problem of welding a shaft or similar part, he will very often make the mistake of strapping the shaft as tightly as possible to a bedplate or in V-blocks, which will prevent the weld from contracting if the clamps are efficient, although actually allowing $\frac{1}{8}$ in. or $\frac{1}{4}$ in. for this contraction. One particularly bad case is reported of "preventing contraction" in which an experienced operator jacked a heavy steel section of a rudder frame apart to allow for contraction in a broken rib 8×4 in. and then proceeded to ram the jack up in the mold box. The result of course was that the section cracked alongside of the Thermit weld and the jack had to be cut in two in order to remove it. But in crankshaft welds the usual result of efficient clamping to keep the pieces in line will be the formation of holes in the weld which in all probability will be blamed on the Thermit, a new crucible, the breaking down of the mold or to other similar causes. Such holes can usually be easily distinguished from ordinary blowholes by the fact that their axes run parallel, or nearly parallel, to the line of the contraction which, in the case mentioned above, is the axis of the shaft.

To show how prone operators are to make this mistake one operator who ordinarily would carefully release the clamps to allow for the contraction of a shaft weld neglected to do so in welding a small trunnion on the end of a heavy steel cross-head. This trunnion was defective and was replaced by welding a piece of 5-in. shafting onto the cross-head. The cross-head was laid on a bedplate and the trunnion was set up in position on a supporting block and strongly clamped in place. The mold was rammed and the weld poured in the usual way with the result that holes, or shrink-holes, occurred parallel to the axis of the trunnion.

Defects That Frequently Occur.—As an illustration of the formation of these holes prick a small hole in an elastic band and then stretch the band. The hole at first is not noticeable, but it will be very noticeable if the band is stretched. The original hole corresponds with the pores that occur in cast metal and the elongated hole is the result of preventing contraction. A similar defect may be caused in a Thermit weld by having a riser with too great a flare, as the sand in the mold tends to prevent the riser from pulling in toward the weld. In this case of course the holes will run nearly parallel to the axis of the riser. This kind of defect frequently occurs and is difficult to overcome where, for instance, the part to be welded is in the crankpin of a shaft and where the slabs or throws are quite close together. In such a case if the sand is rammed tightly between the slabs it will prevent the contraction of the pin weld, and pull-holes parallel to the axis of the pin will be the result.

All of these defects can be corrected or rather prevented in one way or another. In the cross-head weld previously mentioned as well as all shaft welds, rudder-stocks, etc., the lighter part, or section, should be carefully supported on flat blocks so that it will be stable without any clamp and so that it can be moved backward and forward in the line of the weld without affecting the alignment. A strong clamp should then be set in place to hold the pieces in line while ramming the mold, but should be removed from the lighter piece before preheating and pouring. In repairing a break in a small section adjoining two heavy sections it might even be advisable to support one or both of the heavy sections on rollers, as their weight alone might very likely pull holes in the weld.

In welding crankshafts it is customary and best to align the shafts on V-blocks. These V-blocks are heavy pieces accurately machined and slide in a machined slot of a heavy bedplate. The V-blocks should be spaced along the slot of the bedplate so as to correspond with the journals of the crankshaft. Parallel to the main slot of the bedplate and on either side of it are smaller slots similar to those in planing-machine beds. The heads of the holding-down bolts are placed in these slots opposite the V-blocks and a short bar or channel placed across the shaft and clamped down by means of nuts on the holding-down bolts.

The V-blocks should be so placed on the main journals that the shaft can slide at least $\frac{1}{4}$ in. either way parallel to its axis without a shoulder or crank throw striking any part of the V-blocks. Experience has shown that crankshafts usually break in a main journal or in a pin journal close to a crank throw or slab, or the break may occur in the slab itself. It is usually desirable to line up the shaft with the throws in a horizontal position. Let us imagine a shaft with a break in one slab or throw close to the pin journal and the shaft lined up in V-blocks with the throws horizontal, the necessary gap cut out and the wax and mold in place ready to preheat. The operator would probably have a great deal of trouble trying to allow for the contraction and would probably attempt to do this by shifting one part of the shaft about $\frac{1}{8}$ in. along in the V-block and would place various-sized shims in the V-blocks to allow for the contraction along the line of the slab.

Inaccuracy of Alignment Explained.—It would all be simple enough if after pouring the weld the shaft would remain dormant until the weld started to contract when the shims could be removed from one side and placed on the opposite side to allow the slab to contract, but from measurements that have been taken it has been found that immediately after pouring the weld there is a great deal of force exerted, as though a jack were placed between the sections that were fractured. This is of course caused by the intense heat of the Thermit steel conducting into the parts of the shaft adjacent to the weld, causing them to expand. One might suppose that there would be no great force exerted while the metal in the weld was molten, but this can be explained by the fact that the riser and pouring gate have become sufficiently sluggish to hold the more liquid metal below from forcing upward. How-

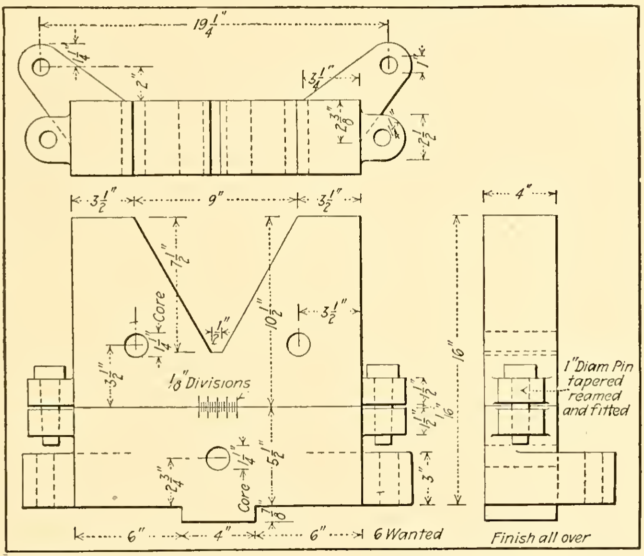


FIG. 27.—Design of V-Blocks for Welding Crankshafts.

ever, the fact remains that the parts of the shafts are strongly forced apart so as to slightly tilt the V-blocks and raise the shaft out of line.

This may explain why the inaccuracy in alignment is not in the direction of the contraction of the weld but almost at right angles to it. In a great many cases this tendency to separate will shift the parts of the shaft horizontally as much as $\frac{1}{4}$ in. and as the V-blocks resist this they are tilted by the force and the shaft thrown out of line.

It may be hours before any considerable contraction sets in, and by this time the shaft has been permanently set out of line. Heating the opposite slab will slightly counteract this, but not sufficiently, because the heat conducted from the Thermit steel will expand one slab a great deal more than any possible preheating on the opposite slab.

Crankshafts that are broken in such a way that they can be lined up with the throws in a vertical position will be almost as far out of line because the sudden expansion of the adjacent parts will have to shift part of the shaft and even sometimes lift it partly out of the V-blocks, and this force is being exerted through molten or perhaps plastic metal so that a certain amount of upsetting will naturally take place.

V-Blocks for Holding Shafts.—In order to overcome these important defects the special V-blocks shown in Fig. 27 will allow a horizontal motion after the mold is rammed. If then the proper allowance for contraction is made the shaft should come back into line because the force tending to separate the fracture will not be resisted and will be subsequently offset by an equal contraction. On the other hand such V-blocks will permit of watching the contractions of the shaft so that different allowances can be made on the next shaft if necessary.

These V-blocks should be made in such a way that they will be divided in two parts horizontally. The upper and lower parts should each have divisions, accurately marked on them next to the dividing line, the central division being longer and heavier than the rest. When the two parts of the V-blocks are central on each other, accurately turned pins, preferably tapered, may be inserted in reamed holes passing through the two lugs so as to securely fasten them together. This locates accurately the central position where the shaft is to be lined up "in line." Where a horizontal contraction is to be allowed for, the pin should be left out of certain V-blocks and the parts of these V-blocks slightly shifted on each other if necessary. If the V-block pins are not in place the holding down bolts can be relied upon to hold the shaft in a desired position during the ramming of the mold. When the preheating is started these bolts should of course be removed and the shaft allowed to move freely. Another advantage of this type of V-block is that flat shims can be placed between the halves of the V-blocks to allow for different journal diameters instead of placing the shims on the slanting face of the V-blocks. The thickness of the shims will of course be just half the difference in the diameters of the journals.

In allowing for contraction of a Thermit weld it must be remembered that the actual contraction of the small amount of Thermit steel in the space between the pieces is almost negligible, whereas the actual contraction of the weld may

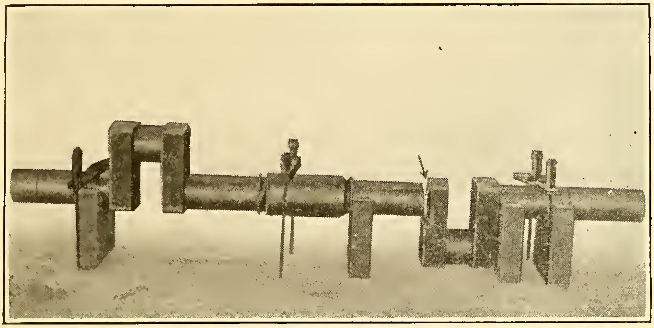


FIG. 28.—Two-Throw Crankshaft—Fracture Cut Away for Welding.

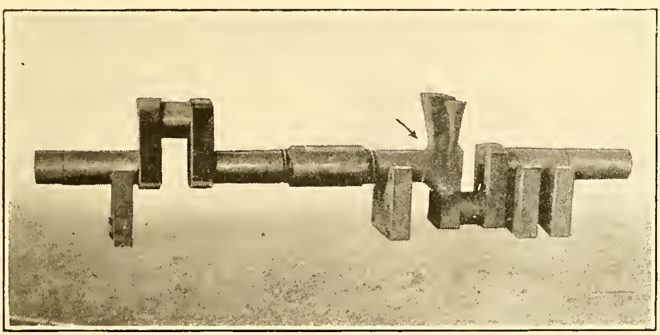


FIG. 29.—Two-Throw Crankshaft Welded—Repair Made in 72 Hours.

vary from $^1/_{16}$ to $^1/_4$ in. This is due to the fact that during the preheating operation the ends of the pieces at the fracture expand or approach each other by the amount of the expansion of the adjacent parts by the preheating. For instance, if the fracture is opened up $\frac{1}{4}$ in. to allow for the contraction and the expansion of the parts during the preheating approach each other almost $^1/_4$ in (perhaps $^1/_{64}$ in. less) the parts should be almost exactly in line after welding. In welding large sections slightly greater allowances for contraction should be made than in smaller ones, because to bring the fracture to the proper heat takes a longer time and consequently the heat "soaks" further along the parts, causing a greater expansion and a greater tendency to close up the distance between the fractures.

A large two-throw crankshaft previous to welding is shown

FIG. 30.—Fracture in Web Cut Away for Welding a Crankshaft.

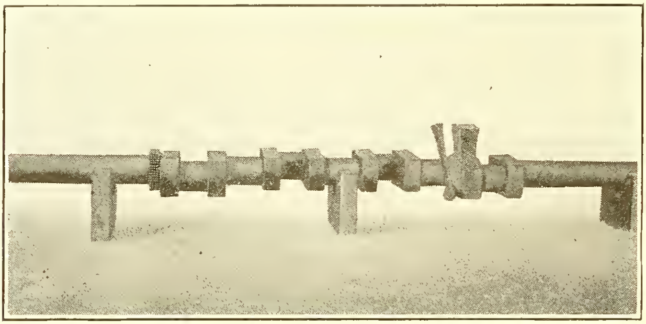


FIG. 31.—Welded in 6½ In. Crankshaft Broken in the Web.

in Fig. 28. This same crankshaft after welding is shown in Fig. 29. A 6½ in. crankshaft broken in the web is shown in Fig. 30 and the finished weld in Fig. 31.

How to Locate Minute Cracks in Crankshafts or Other Parts.—In the course of welding crankshafts and other important work it is often found that while the part to be welded is broken clear through there are other minute hairline cracks near by which are sure to give trouble later. It is probable that the strain thrown on the part when the break occurs is often sufficient to start these small cracks. They may also be caused by strains in the metal from improper treatment in the first place, and which may have been responsible for the first break.

In any case, however they may have been caused, the proper thing to do is to locate these cracks and so weld the parts as to eliminate them. As they are many times so minute as to be invisible to the naked eye some other means must be found to locate them. A very efficient method is to paint the entire section with a mixture of whiting and alcohol. The whiting and alcohol should be mixed so as to form a good white paint, but not too thin. This dries quickly and becomes discolored by the grease or dirt in the very fine cracks, so that these cracks show up very distinctly. Since it is the oil or dirt in these cracks that causes them to show so clearly on the white paint it is not a good method to detect cracks in a new piece. The part to be painted should of course be cleaned of all the dirt and grease on the surface. It is a conservative estimate to say that probably one-third of all crankshafts will be found to contain additional cracks other than where the break is visible. If these are not found and remedied the chances are that they will develop into real breaks later.

Welding New Teeth in Large Pinions to Replace Teeth Broken Out.—The Thermit process is coming into more and more general use in large steel works and rolling mills for welding teeth in heavy pinions, as it can be relied on to give a permanent, efficient and economical repair in the case of these very heavy sections.

The following instructions cover a method which has been in use for several years, and if they are carefully followed a satisfactory repair is assured. Many pinions weighing up to 17 tons have been repaired in this way and are now doing service.

The repairs usually consist of replacing teeth or parts of teeth which have broken out. They are peculiar in that the tooth is a comparatively small projection on an extremely heavy steel casting. For this reason, if the repair were attempted by the ordinary method, i.e., if the casting were preheated at the weld only as covered in previous instructions for making Thermit welds, the heat would be carried away into the castings so quickly, especially during the interval of removing the preheating burner and tapping the crucible, that in most cases a poor weld would result. Everything possible must therefore be done to conserve the heat at the weld, and to do this efficiently it is necessary that the whole pinion should be heated to a red heat. This may be done by bricking in the heaviest part and preheating it by means of oil or gas burners conveniently placed while the part to be welded is being preheated in the regular way. The Thermit company's flaming-burner preheater attachments are admirably adapted to this preheating work, as they give an extremely hot flame which may be adjusted to suit the conditions. Care should be taken, however, to bring up the heat slowly, as otherwise there is danger of cracking the pinion.

In making all welds where a relatively small amount of Thermit steel is to be added to a heavy steel casting or where one or both of the parts to be joined is considerably heavier and larger than the Thermit steel part it is necessary to take special precautions to secure thorough amalgamation of the Thermit steel with the heavier part, especially at the extreme edges of the line of junction where in service the greatest strain will come. The slightest imperfection at this line of junction or extreme fiber will cause a tear to start in service which will cause a fracture of the welded part. A perfect weld on this extreme fiber is made more difficult by the fact that the metal in the weld always shrinks a little more than the white-hot steel of the pinion due to the slight difference in shrinkage between molten steel and white-hot steel. It is necessary therefore that the fusion be obtained for a considerable depth even at the extreme edge of the Thermit steel. Fusion at this point is more difficult because the heat of the Thermit steel comes from one side only and not from all sides as it does near the center of the weld.

For all these reasons it is desirable to increase as far as possible the surface exposed to the Thermit steel in the width of the weld. This at the same time produces edges or corners which melt more readily and thus aid in the fusion. These edges may be readily produced by cutting out a groove or slot in the main body of the pinion at the center part of the root of the tooth broken out. This slot should be half the

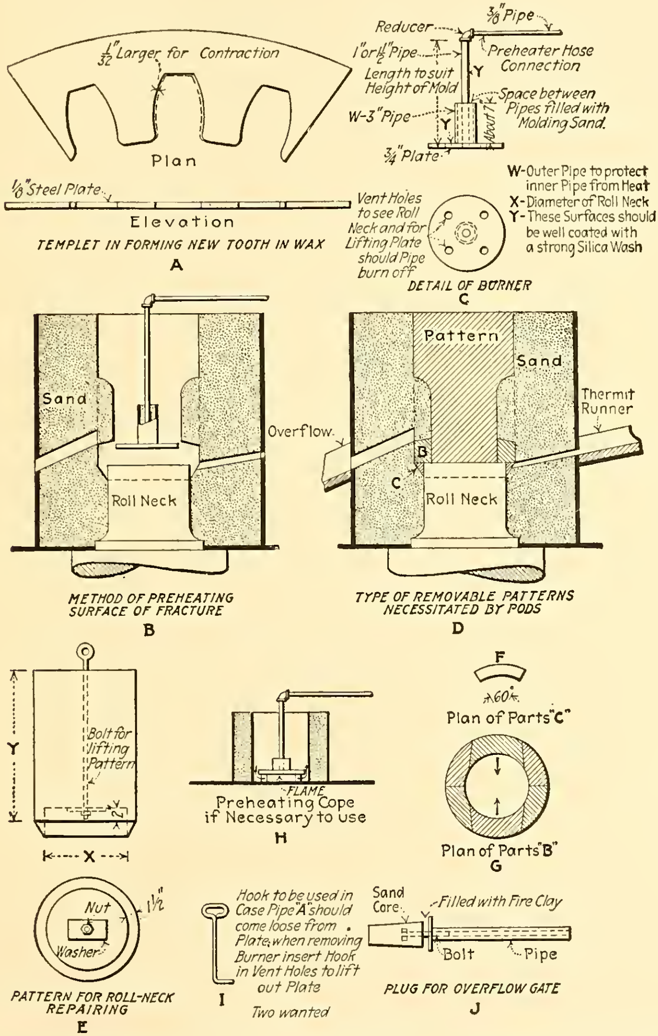


FIG. 32.—Designs for Patterns and Heating Apparatus for Repairing Steel Pinions.

width of the tooth in depth and also in width, i.e., if the tooth to be welded in is 6 in. wide at its root the slot should be made 3 in. wide by 3 in. deep. The most economical way to cut this slot is to place the pinion on a planer and machine it out.

The cutting of such a slot also serves to bring the line of junction between the Thermit steel and the metal of the pinion well into the body of the pinion so that a strong and efficient weld is assured.

After the slot has been cut, the pinion in the vicinity of the weld should be carefully cleaned and then mounted vertically for the welding operation. In this mounting great care should be taken that the pinion is properly supported so that there will be no danger of its settling under the added weight of the mold box. This can be accomplished in the following manner:

First dig a hole in the ground the proper size to receive the neck of the pinion. Then lay two T-rails across the top of the hole so that they will come underneath the shoulder of the pinion. If the ground is not sufficiently hard to properly support the T-rails steel plates can be placed underneath in order to prevent the rails from settling into the ground.

Making the Wax Tooth Pattern.—With the pinion properly supported in this manner the next step is to provide the wax pattern for the new tooth. This can best be done by constructing a rough wooden box a little larger than the tooth in question. Place this against the pinion where the new tooth is to be added and lute around the edge of the box with fire clay. Next fill this box completely with molten wax. When the wax has set remove the box and shape to proper form by means of a templet as shown in *A*, Fig. 32.

This templet should be made from $\frac{1}{8}$-in. steel plate and the outline of the teeth cut into it by using three good teeth in the pinion as a guide. The center tooth, however, which will be the guide for the tooth to be welded in, should be cut $^1/_{32}$ in. larger all around so as to allow for the contraction of the Thermit steel tooth. The two outside teeth of the templet engage with the teeth on each side of the wax pattern, and therefore when this templet is moved up and down it will cut the wax to proper shape and also assure that the new tooth is welded on in proper pitch.

ANOTHER METHOD

One disadvantage of this method of making the wax core is that if the adjacent teeth are considerably worn the new tooth will not conform to their shape unless the templet is juggled considerably when shaping the wax pattern. A newer method has recently been developed by F. N. Keithley and used with success. This method gives a cast tooth of the same

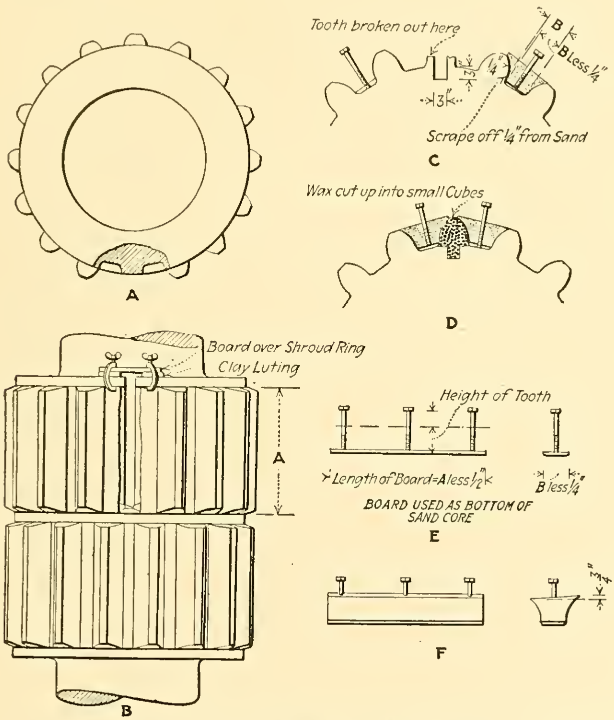


FIG. 33.—Recently Developed Method of Making Wax Tooth Pattern.

approximate shape as the others in the pinion, even if considerably worn, which is an obvious advantage.

Referring to Fig. 33 the broken tooth is slotted out as in the previous method and the adjacent teeth are cleaned and scraped. With the pinion in a horizontal position wooden strips are fitted to the bottoms of the tooth spaces, as shown at the left in *C*. Lag screws are screwed into these for handling purposes. Further details of the strips are shown at *E*. A mixture of two parts building sand to one of fire clay is sifted through a No. 4 mesh riddle and moistened a little more than for ramming a mold. If this mixture does not draw well more fire clay may be added. The mixture is pressed between the model teeth on top of the board strips, as shown at the right in *C*. The mixture is rammed in firmly to a point $\frac{3}{4}$ in. above the top of the tooth on the side for the wax pattern, as indicated at *C* and at *F*. The idea is to provide sufficient height of wax to allow for shrinkage.

After the two parts are rammed they are lifted out and laid carefully on a board. One-fourth of an inch of material is then carefully scraped off of the side of each piece that does not come in contact with the wax, and the surfaces are slicked. This is to allow for shrinkage of both wax and Thermit steel. The two pieces are now placed in position as shown at *D*. Weights should be placed partly on the pieces and partly on the adjacent teeth to hold the pieces in place. The ends are then luted with fire clay and the space filled with small pieces of wax. The melted wax is then poured in, taking care not to have it too hot, as it will eat into the sand if it is.

The mold parts in position and the wax poured are shown at *D*. If the pinion is shrouded the wax pattern for the shroud can be put on at the same time that the wax tooth is formed. It is only necessary to roll a clay rod about 1 in. in diameter and lay it against the pinion 3 in. away all around from the space cut in the shroud. Back this up with a board large enough to extend above the top of the tooth and lute as indicated at *B*.

When the wax pattern is finished the mold box should be placed in position and securely clamped to the pinion, the clamps to be in a position so as not to come in contact with the fire when the pinion is being preheated.

This mold box should be wide enough to take in two teeth on each side of the tooth to be welded. Now ram up the mold box, allowing for a preheating gate, a pouring gate and a riser in accordance with instructions already given. When this is completed construct a brick furnace around the exposed part of the pinion and about 2 in. away from the teeth. Next place a sheet-iron casing around the exposed neck on top.

This casing should be 6 in. larger in diameter than the neck and about 4 in. higher. Now ram sand between the casing and the neck and cover the top with a layer of sand 4 in. thick. In this way the entire pinion is insulated.

Preheating.—The next step is the preheating. Place a burner at the bottom of the brick furnace as shown in Fig. 34, and start with a very mild heat. This is to avoid heating

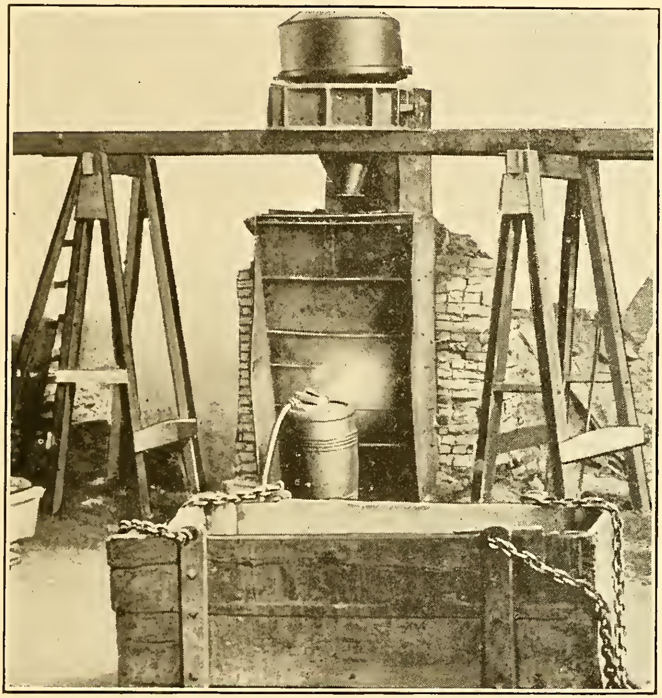


FIG. 34.—Mold Box, Brick Furnace and Crucible in Position and Pinion Being Preheated.

the pinion too quickly, thus causing internal strains which might result in cracking the pinion. After the pinion has been thoroughly soaked with heat the fire can be increased to a good sharp heat so as to bring the entire pinion to a good blood red or about 1200 deg. Fahrenheit.

While the heating is in progress, as shown in the rear view, Fig. 35, place an automatic crucible of the proper size to hold the Thermit charge in position over the pouring gate and charge with the welding portion of Thermit. In case of very large welds it is sometimes necessary to use two crucibles and provide two pouring gates in the mold.

Repairs of this kind usually require anywhere from 350 to over 1000 lb. of Thermit.

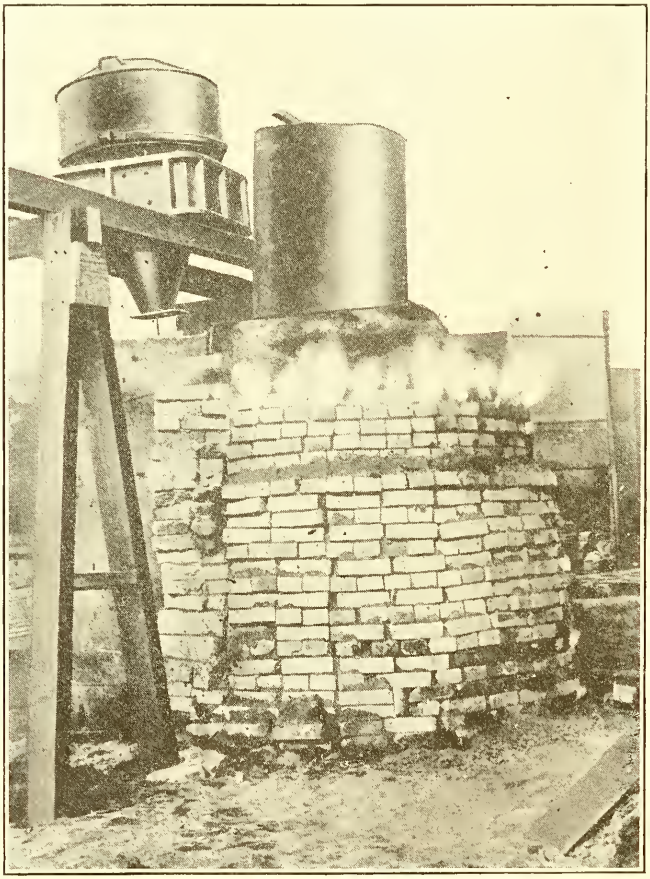


Fig. 35.—Rear View Showing Preheating of Body of Pinion in Brick Furnace.

In special cases it is advisable to make up a special steel mixture of essentially the same analysis as that of the pinion.

Continue heating in the brick furnace until the Thermit steel has cooled to about the same temperature as the body of the pinion, then remove the burner from the furnace, take off a few of the top bricks and fill in between the bricks and the pinion with dry sand, thereby protecting the pinion completely from the air currents.

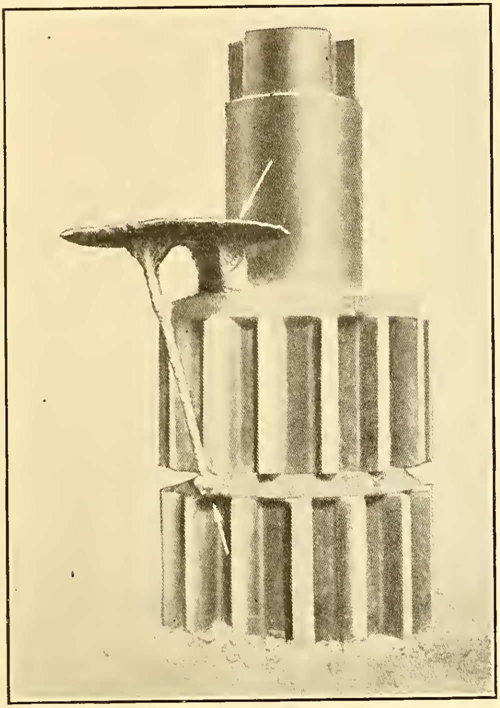


Fig. 36.—Finished Weld, Showing Metal in Pouring Gate and Riser.

The pinion should be allowed to cool slowly in this mold for at least six or seven days so as to thoroughly anneal the metal in the entire piece. The mold can then be dismantled, the weld trimmed and the pinion will be ready for service. A pinion previous to trimming is shown in Fig. 36.

CHAPTER V

WELDING NEW NECKS ON LARGE STEEL PINIONS AND OTHER HEAVY WORK

Frequent breakages of heavy pinions in steel plants have resulted in the development of a very ingenious adaptation of the Thermit process for their repair. Obviously the casting on of a new neck entirely out of Thermit steel would be a very expensive operation and it would also be costly and difficult to turn up a new piece of steel and weld it on to the original section, as the weld would be a very large one to make. Experience has shown, however, that the intense heat of the reaction can be utilized for the purpose of bringing the broken surface of the pinion to a fusing temperature, at which time a supply of liquid steel can be poured in from the ladle, and this will unite with the original body of the pinion to form a new neck thoroughly amalgamated with the rest of the piece.

Briefly the operation consists in constructing a mold around the broken section so as to permit of casting on a new neck to replace the one broken off. The original section is then preheated to red heat by means of gasoline or oil burners, after which Thermit steel from a crucible is allowed to flow over the fractured surface to a depth of 1 in. This completes the heating operation and brings the surface of the roll to the melting point. A supply of liquid steel from a ladle is then tapped into the mold and allowed to wash through and overflow into an ingot mold so as not to be wasted. The overflow gate may then be closed and the mold filled to the top with steel. Detailed instructions for these various operations follow, but it is recommended that if the process is to be used for the first time for such repairs an experienced engineer should be obtained to supervise the first welds and give personal instructions for executing this class of work.

The instructions given here have been written more especially for the purpose of acting as a guide for a reference, and while we hope that there are sufficiently adequate and complete to enable anybody to make these welds, the personal supervision and instructions of an experienced engineer are much to be preferred.

Two Methods of Working.—We give two methods for executing these repairs. The first method which follows is undoubtedly the safest and surest method to use, but it involves considerably more trouble and expense than the second method. We can recommend it strongly, however, and believe it would be to the interests of steel plants having much of this work to do to equip themselves properly to follow out this method.

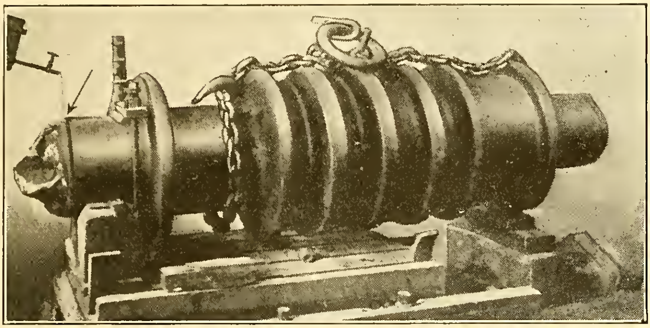


Fig. 37.—Sawing Off End of Neck Previous to Welding on a New One.

Before undertaking a pinion repair the broken end should be cut off square, as shown in Fig. 37, so as to form a level surface when the roll stands in a vertical position. The object of this is to permit of a uniform covering of Thermit steel over the entire surface to be welded. If the break is in the pods, cut off 2 in. below the point where the pod joins the neck. If when the neck is cut off it should be found to contain any pipes or cavities these should be bored out and steel plugs turned to a driving fit and driven into the cavities at least 5 in., care being taken that the plugs are driven in even with the surface on the end of the neck.

Another and better method is to dry out the inside of the cavity by heating and then fill with liquid steel. This will eliminate any danger of the Thermit metal melting the plug and running into the cavity, which might cause a violent and dangerous eruption of the steel. Clean off all dirt and grease at least 20 in. from point of weld.

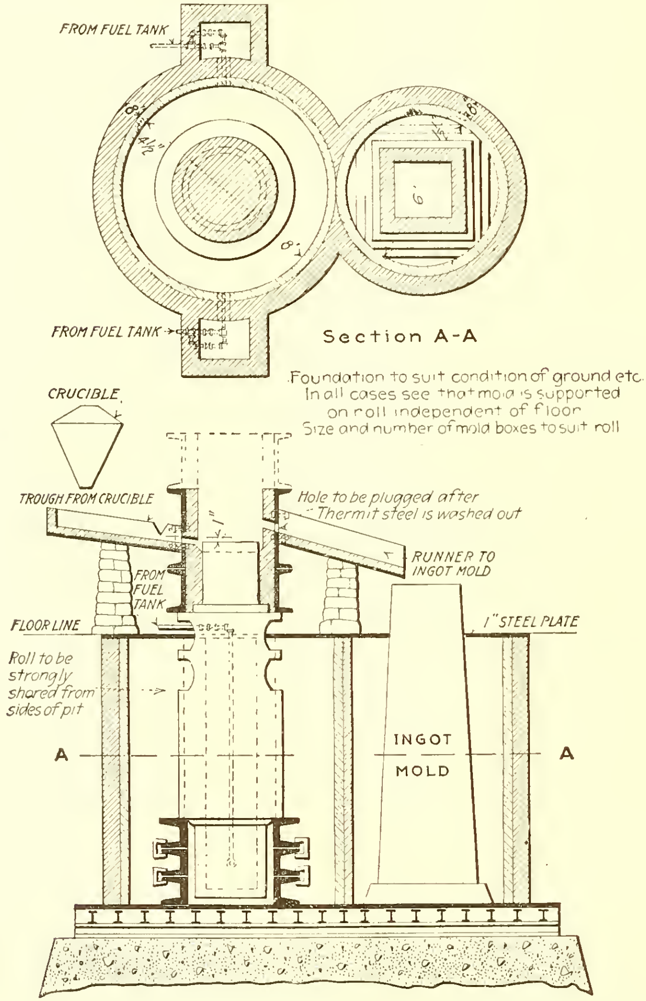


Fig. 38.—A Design for a Permanent Pit for Welding Necks on Large Rolls and Pinions. If Desired a Removable Fire-Brick Partition May Be Used Between Roll or Pinion Pit and the Ingot Mold Pit.

A riser pattern should be provided, undercut as shown in Fig. 32-D, also a pouring gate and overflow gate pattern.

The riser pattern should be 3 in. larger in diameter than the pinion neck, and at the lower part, where it joins the neck, it should taper as shown. Where the operation requires the casting of pods a special pattern should be made having the shape of the pinion neck with these pods. This pattern, like the riser pattern mentioned before, should be larger in diameter than the pinion neck and should taper at the bottom. The pattern should, if necessary, be made in sections so as to allow of being withdrawn from the mold.

Foundation and Heating Arrangements.—Heavy circular cast-steel mold flasks should be provided, the same as are used in steel-foundry practice. In the absence of these flasks suitable ones can be made of $\frac{1}{4}$-in. steel plate. The bottom flask should be divided and bolted together so that it can be removed without trouble, as it is much easier to tear down the mold after this flask is removed than before.

In undertaking repairs on these pinions it is recommended that a special pit be constructed as shown in Fig. 38. It is of the utmost importance when constructing the pit to provide a good foundation for the bottom of the pit. It has been found in many cases that steel plants are built on low and marshy ground, therefore when a pit is dug the ground is apt to be soft and many times water seeps in. For this reason the design in Fig. 39 is shown. However, unless precautions are taken to provide a good foundation heavy pinions are apt to settle before the welding operation is completed. This is liable to cause a loss of the repair and sometimes a serious explosion might result caused by the hot metal coming in contact with moisture. When an adequate foundation has been provided set the pinion and the ingot mold in place and brace them strongly to the sides of the pit.

Arrange the heating burners which may use gas, gasoline or kerosene. This arrangement is shown, although the complete connection to the fuel supply is not.

Constructing the Mold.—Construct the mold, as shown, of sharp silica sand and fire clay. The usual proportions of the mixture are three parts of sand to one of clay, but this varies according to the sand and clay used. Coat the mold with a good steel wash and drive in nails or chaplets to hold the sand in position.

Attach the runners at the proper points and ram them with the same material, being careful to arrange the runner for the Thermit exactly as shown, that is, the runner gate is so

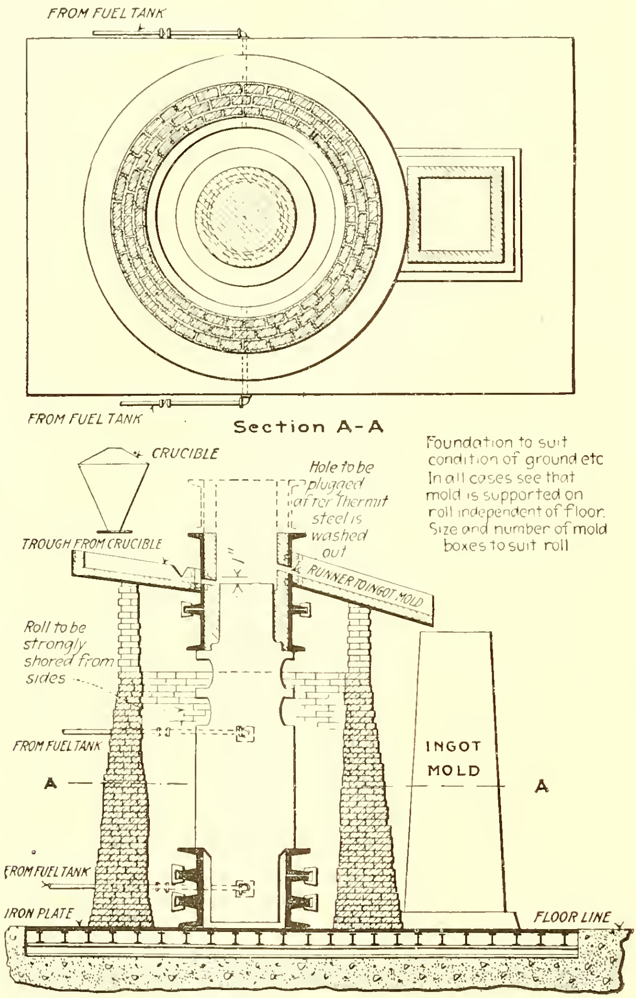


Fig. 39.—Method of Welding Roll Necks Without Digging a Pit.

placed that when the Thermit steel has run into the mold the top surface of the neck will be covered with superheated Thermit steel to a depth of about 1 in., and the slag from the Thermit reaction will flow from the crucible and run out of the V-shaped notch in the side of the runner, thereby preventing any slag from entering the mold.

The overflow runner should have sufficient pitch so that the liquid steel will flow to the ingot mold readily without spattering. Firebricks should be laid on top of the ingot mold in order to prevent steel from spattering at that point.

When the mold is completed start the preheating of the body of the pinion. If gasoline or kerosene is used three double or five single preheaters will be required and another one should be kept filled and ready to be cut in when any one of the others has become empty. This will prevent loss of heat while a preheater tank is being refilled.

As the body of the pinion approaches a red heat start the preheating cf the top of the neck as shown in Fig. 32-B. Heat this surface to a good red heat, timing the operation so as to have both neck and body of pinion red hot at the time the openhearth steel is tapped out of the furnace.

While the preheating of the neck is progressing set the automatic crucible, size 7, charging it in accordance with previous directions, so that it will be ready when needed.

Amount of Thermit Required.—In calculating the amount of Thermit required for this type of repair allow 75 lb. of railroad Thermit for each square foot of surface it is desired to melt down.

Be sure that the cope has been baked while the preheating of the neck is going on (either in an oven or as shown in Fig. 32-H) and is located conveniently so that it can be brought up with the crane at the proper time. After the furnace is tapped raise the ladle of steel and try the stopper by making a couple of pours to be sure that the stopper works properly and will shut off tight.

Move the ladle to a point near the mold so that no time may be lost between pouring the Thermit steel and washing through the steel from the ladle. *Remove the preheaters to a safe distance.*

Ignite the charge of Thermit in the crucible, and when the reaction is over (usually 35 to 50 sec.) tap the Thermit steel into the mold, as shown in Fig. 40. When all the steel from the crucible has flowed into the mold the slag will commence to run over the V-shaped notch in the pouring runner. Move the crucible out of the way and plug the pouring gate with a sand core provided for this purpose, banking up securely behind it to prevent leakage.

Lower the ladle of openhearth steel, shown at the left, to a point close to the top of the mold and tap the steel into

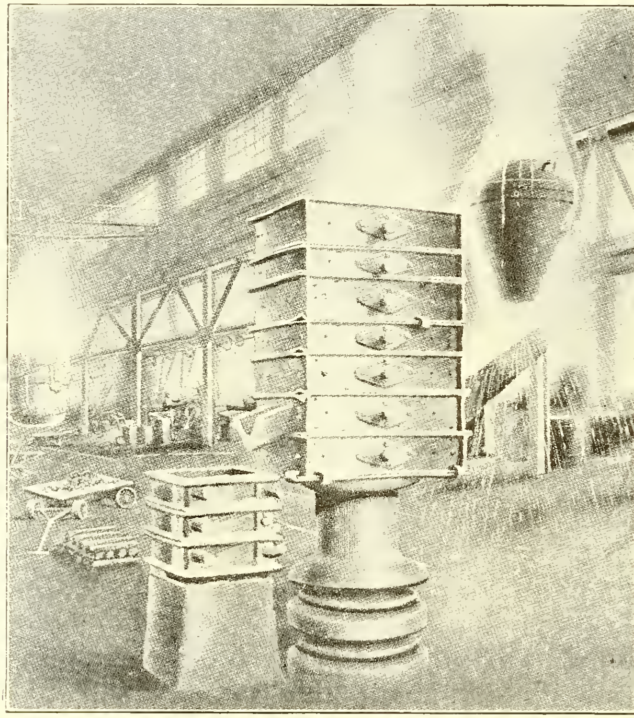


Fig. 40.—Welding a Roll Neck. Thermit Steel Tapped into Mold and Ladle of Steel at Left Ready for Final Operation.

the mold, running through about 5000 lb. into the ingot mold which has been set for the purpose, as shown.

Plug the runner gate with a core constructed as shown in Fig. 32-J and bank up well behind it so that there will be no danger of a runout. *Be careful in plugging this gate on account of its size.* After the plugging is completed and banked up, the sand should be weighted down as an extra precaution to prevent accident.

After the overflow has been securely plugged fill up the mold with steel from the ladle and cover it well with dry sand or charcoal to keep the metal hot.

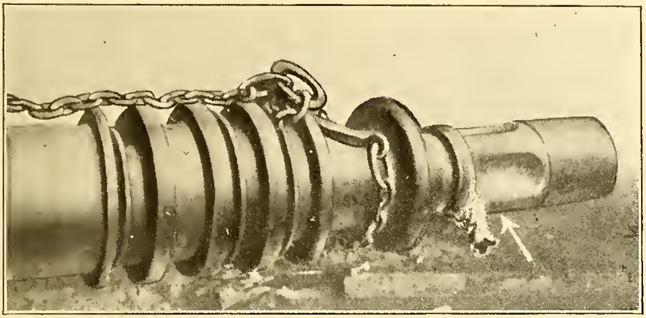


FIG. 41.—Roll Neck Welded to Large Steel Roll with Pods Cast in.

Treatment When a Cope is Used.—If a cope is used clean off the surface of the top of the mold and set on the cope, clamping it securely, and then fill the cope to the height desired

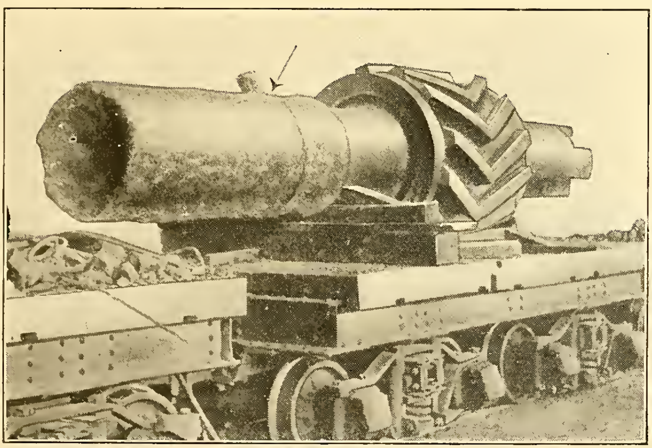


FIG. 42.—New Neck Welded to Large Steel Pinion. In this Case the Pods Were Milled Afterward.

with steel and again cover over with dry sand or powdered charcoal.

If the body of the roll or pinion has cooled to any extent it would be desirable to again preheat it. After the body of the pinion is sufficiently preheated cover the pit to make it as nearly airtight as possible, so as to cause the roll or pinion to cool slowly. By doing this further annealing is unnecessary.

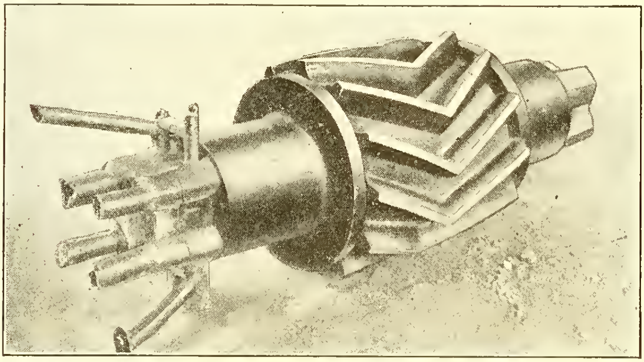


Fig. 43.—Worn Pods Built Up with Thermit Steel. The Repair Consisted of Four Welds Made Simultaneously, using Two Pouring Gates and Two Crucibles.

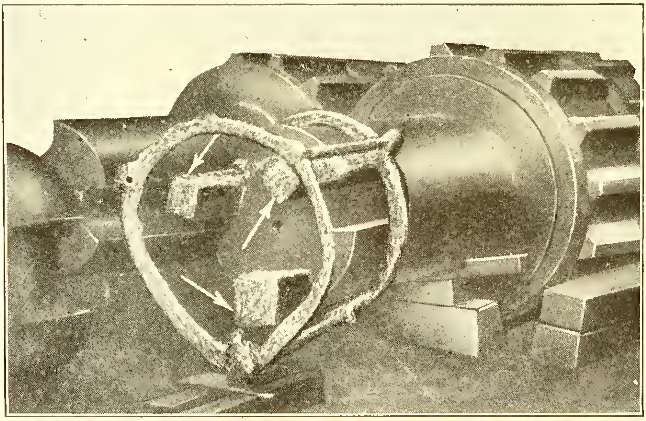


Fig. 44.—Building Up Worn Pods by Means of Three Thermit Welds. Pouring Gates Were Connected at Top and Bottom to Insure Equal Distribution of Metal.

After the pinion is sufficiently cool (usually about 48 hours or more) remove from the mold and machine to size.

In some steel plants it is considered preferable not to use a cope but to build the mold all in one piece to the height of the new neck. This method simplifies the making of the mold and the pouring of the weld, but sometimes complicates the operation for the following reasons:

When riser patterns are withdrawn it is a little more difficult to remove loose sand from the mold.

In preheating it is not so easy for the operator to see what he is doing.

There are times when these necks will be as much as 5 ft. high, which makes it a little unhandy to work around the mold.

There are numerous arguments on both sides of the question, but we feel that either method will give good results. For short necks, however, a cope can probably be dispensed with without introducing any difficulty.

Two welding jobs just as they came from the molds are shown in Figs. 41 and 42. The first is a neck welded onto a large steel roll with the pods cast in. The second one shows a new neck welded to a large steel pinion. In this last case the pods were milled out afterward.

Two other welding jobs are shown in Figs. 43 and 44. These both illustrate the repair or replacing of worn pods on heavy steel mill pinions.

Alternative Method.—While the preceding directions cover the welding of pinions under what might be considered ideal conditions it is not always possible to do the work in this way, and where such is the case we would recommend that the following directions be followed, as they represent a simpler method, yet one which has always resulted in satisfactory repairs.

Patterns, mold box, runners, etc., should be constructed in accordance with directions given for the previous method.

In these repairs great care should be exercised in supporting the pinion so that there is no danger of its settling under the added weight of the mold and the steel which is poured into it. If it is not desired to go to the expense of constructing a special pit as outlined in the previous method a satisfactory and economical way is to dig a hole in the ground about 8 ft. in diameter and of sufficient depth to receive at least $\frac{3}{4}$ of the entire length of the pinion. Cover the bottom of the hole by laying a double flooring of 2-in. planking, being careful that the planks in one layer run in opposite directions to those of the other layer.

On top of this place a steel plate in order to distribute the weight of the pinion over the entire floor area. Such a foundation has always proved adequate and is not expensive.

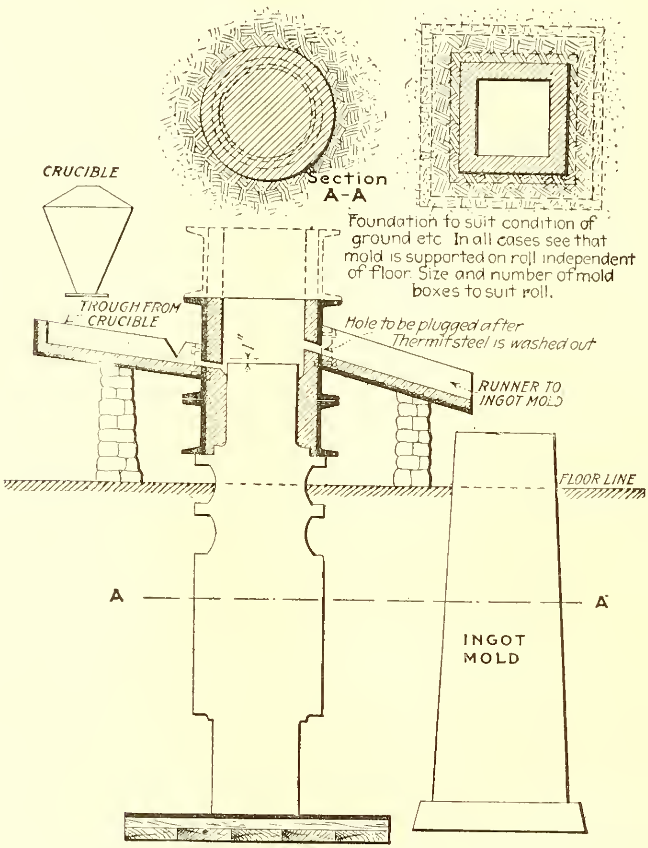


FIG. 45.—Alternate Method of Supporting Roll or Pinion to Be Repaired.

Set the pinion in the hole so that the surface to be welded is level and fill in all around the pinion with dirt, ramming hard to hold the pinion permanently in position.

Dig a second hole alongside of the buried pinion to receive the ingot mold. This should be at such a distance from the pinion that a suitable runner for the overflow steel can easily be placed. The top of the ingot mold should, of course, be lower than the top of the roll or pinion neck.

If the neck is broken off close to the body of the pinion it is absolutely necessary to provide arrangements for preheating the body protruding above the ground in order to avoid shrinkage strains. A simple way to do this is to build up a brick furnace and heat in accordance with directions relating to casting of teeth in large pinions, and more of the pinion body should protrude above the ground than shown in Fig. 45. If, however, there is one foot or more of neck protruding from the body of the pinion, it is not absolutely necessary to preheat the rest of the pinion.

THE MOLD BOX

The mold box should be constructed with heavy steel flasks or a substitute made of at least $\frac{1}{4}$-in. plate and should be supported entirely on the roll and independent of the ground.

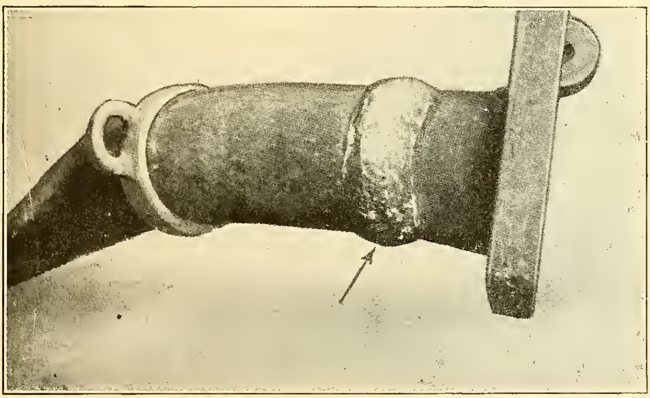


FIG. 46.—Finished Weld on Anchor Davit of U. S. S. "Olympia."

With the mold box adjusted in place ram up with good molding material in accordance with the previous directions and then draw out the various wooden patterns. Nails or chaplets should be driven into the sand so as to hold it firmly in place. It is advisable to coat the mold with a good steel wash. When the mold is completed the preheating of the body of the pinion should be started if the repair is of such a nature as to require this preheating. If this heating is not necessary start preheating on top of the neck as shown in Fig. 32-B. If the body of the pinion is heated the heating of the neck should not be started until the pinion approaches a red heat.

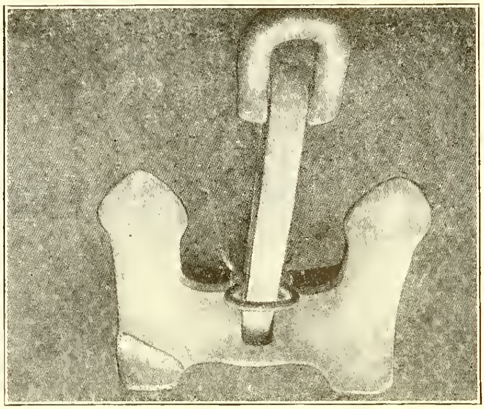


FIG. 47.—Anchor of the Morgan Yacht "Corsair" Repaired with Thermit.

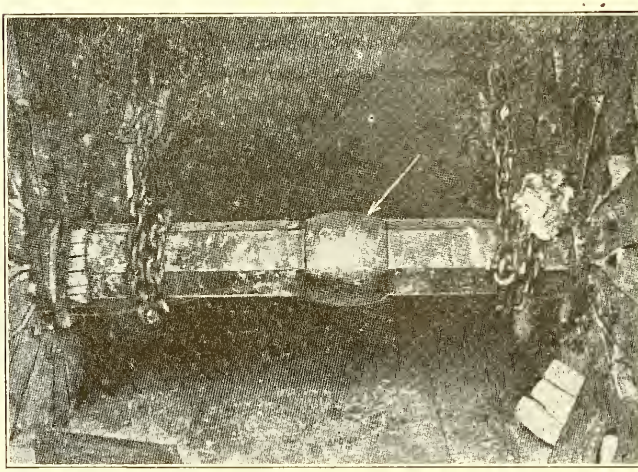


FIG. 48.—Weld on Wheel Shaft of Steamer "Nashville" on the Cumberland River, Made in 1912.

Heat the surface on top of the neck to a good red heat, timing the operation so that it will be red hot at the time the openhearth steel is tapped out.

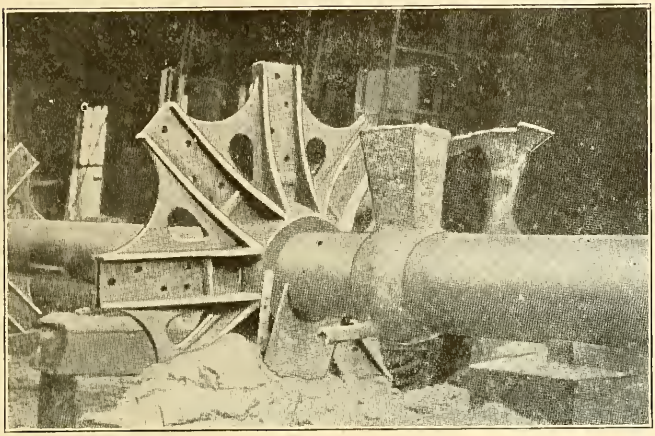


FIG. 49.—Weld on 10-in. Wheel Shaft of Steamer "Osceola," Made at Jacksonville, Fla., in 1915.

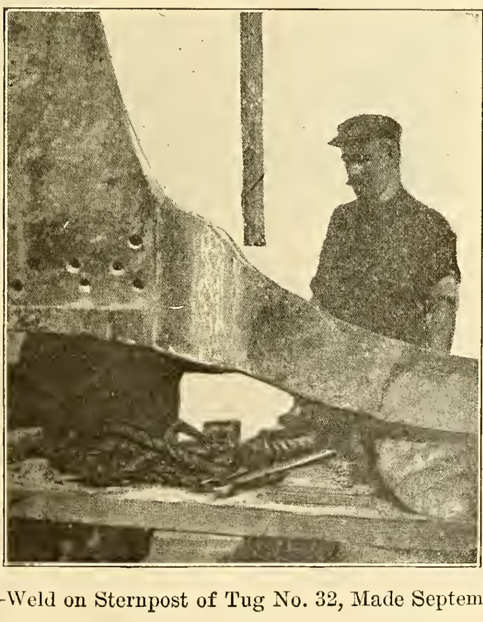


FIG. 50.—Weld on Sternpost of Tug No. 32, Made September, 1911.

While the preheating of the neck is progressing set an automatic crucible, size 7, as shown in Fig. 45, and charge it so that it will be ready when needed. If possible it is best to support the crucible with a crane so that it can be quickly removed after it has been tapped. The procedure is then the same as described for the previously given method. After cooling, strip the mold and machine the parts to proper size.

It is sometimes desirable where the body of the pinion has been preheated to continue this heating after the weld

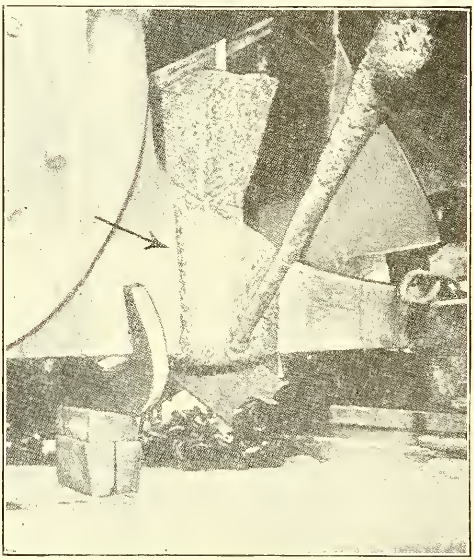


FIG. 51.—Sternpost Weld on the "William Henry Mack," July, 1912.

is completed. This can easily be done by again igniting the burners directed into the brick furnace. After the body is sufficiently preheated remove the burners and fill in between the bricks and the pinion with dry sand so as to cause slow cooling. By doing this further annealing is unnecessary. As previously mentioned, a cope may or may not be desirable, and this is left to the judgment of the operator.

Marine Work.—The general principles to be followed in making marine repairs are the same as for any other repairs of a similar size and nature, so no detailed description need be given. However, it will be of interest to know the exact nature of some of the more common repairs made on anchors, wheel shafts, sternposts or the like, so a few views of some of the actual repairs are shown. A big point in favor of the Thermit process in cases like the ones given is the short time necessary for the ship to be laid up. In many cases little or no dismantling is necessary. In a number of stern shoe welds on lake steamers the sizes of the parts at the break have

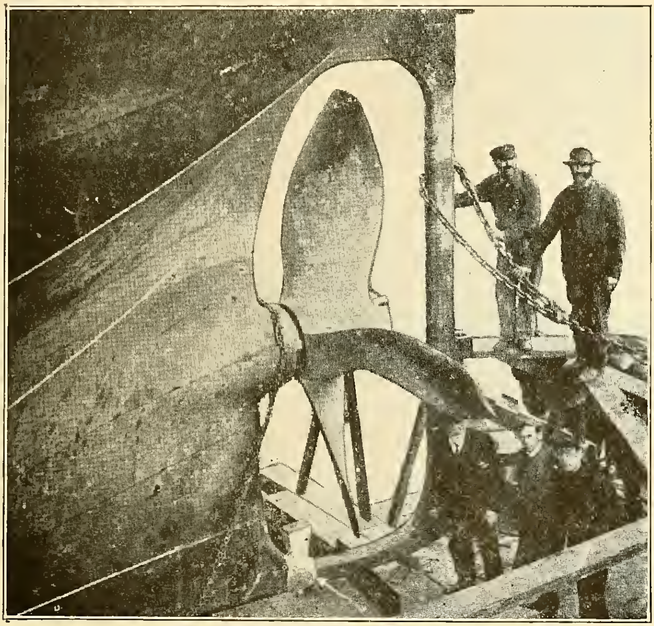


Fig. 52.—Another Sternpost Weld. S. S. "Corunna" of the Canadian Lake Transportation Co., Made in 1907.

been from 11×16 in. to 10×20 in. or more, and the average time required has been about 36 hours complete. On a large number of ocean-going vessels the welds made have been on sections of larger dimensions than those quoted.

In Fig. 46 is shown a weld on the anchor davit of the famous U. S. S. "Olympia." Fig. 47 shows a repair on the anchor of the Morgan yacht "Corsair." Fig. 48 is a repair on the wheel shaft of the "Nashville," a Cumberland River steamboat, made in 1912. Fig. 49 shows a repair on the wheel shaft of the river steamer "Osceola," welded at Jacksonville, Fla., in 1915. Fig. 50 shows a sternpost weld on a tug, made in 1911. Another sternpost weld is shown in Fig. 51. Still another very similar weld is shown in Fig. 52. These are sufficient to give the reader a good idea of the application of the process to this class of work.

CHAPTER VI

RAIL WELDING FOR ELECTRIC SYSTEMS

Probably no problem in recent years has received more consideration at the hand of traction companies than the subject of track construction and maintenance. Progress along this line has been continuous and expense has not been spared to obtain the best roadbed possible; heavier rails are being used and particular attention is paid to the foundation, ties and drainage; everything is of the best material and workmanship until it comes to joining the rails together, and here there usually develops the weak point of the entire system. This refers to the mechanical joints in common use. No matter how much care is taken in applying splice bars mechanical discrepancies and disadvantages cannot be overcome; the rail sections are seldom uniform and the American Society for Testing Materials has adopted specifications which limits a maximum difference in height to $^3/_{64}$ inch. Variable height in new rails is often unavoidable, as joint plates fitting one rail perfectly may not fit its neighbor.

There are many reasons why the mechanical joint fails to fulfill its function, which are not necessary to enumerate here. On the other hand the advantages of a welded rail joint, where circumstances will permit, are plain. While there are several systems by which rail joints may be welded, at the present time the Thermit method is the only one that absolutely eliminates the joint. It also has advantages in the modified joint-welding work. These advantages will become clear as our description of the actual processes develops. Briefly, the weld is accomplished by pouring the superheated steel obtained from the Thermit reaction into a mold surrounding the rail ends at the joint. This fuses with the base and web of the rail as well as with the lip and one side of the head. An insert cut from a rolled section of similar analysis to that of the rail itself is placed between the heads at the running face, and the lower part of this insert is melted into the Thermit steel. The mold is so constructed, however, that the head of the rail and the top part of the insert are not melted but are merely heated to a welding temperature, so that when the Thermit metal begins to cool and contract, thus drawing the rail ends together with tremendous force, the squeezing action on each side of the insert thoroughly butt welds it into the head. When this has been accomplished the running face is ground to a true surface and the surplus metal ground out of the groove. The weld obtained in this way is so perfect that it is practically impossible to detect its location after the rails have been paved in.

In practice the welding is best done after the ties have been concreted. If the welding is done before the concreting it is somewhat difficult to keep the rails in perfect alignment and to proper surface after the temporary splice bars have been moved. The rails are spaced $\frac{3}{4}$ in. apart and must be thoroughly cleaned for a distance of 4 in. from each end. This can be accomplished by using a small steel-wire brush. The ends of the rail heads must next be cleaned and where necessary filed smooth so that when the insert is fitted the maximum amount of contact surface will be obtained. In other words the insert must be made to fit accurately. Following this the rails are brought to proper surface and alignment, care being taken to keep the rail ends a trifle high, so that when a straightedge about 30 in. long is centered over a joint there will be a space of about $^1/_{32}$ in. between the ends of the straightedge and the surface of the rail directly under it. This slight raising of the rail ends has been found necessary in practice, as it assures proper alignment and surface after grinding.

PLACING THE INSERT

The joint is now ready for the placing of the insert, as shown in Fig. 53. Various thicknesses of inserts must be kept on hand to fit the variation in gap brought about by temperature changes and other causes. With the inserts in position two part sand molds are applied, as shown in Fig. 54. these are rammed in advance on a foundry squeezing machine over a wooden pattern, the dividing line of the molds being

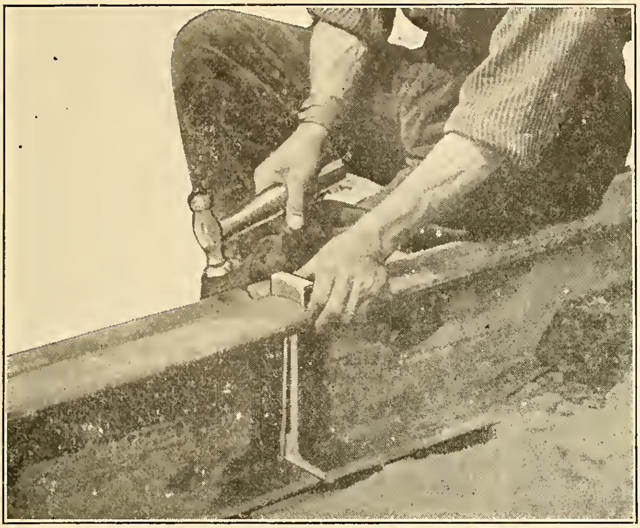


Fig. 53.—Adjusting Insert Between Rails.

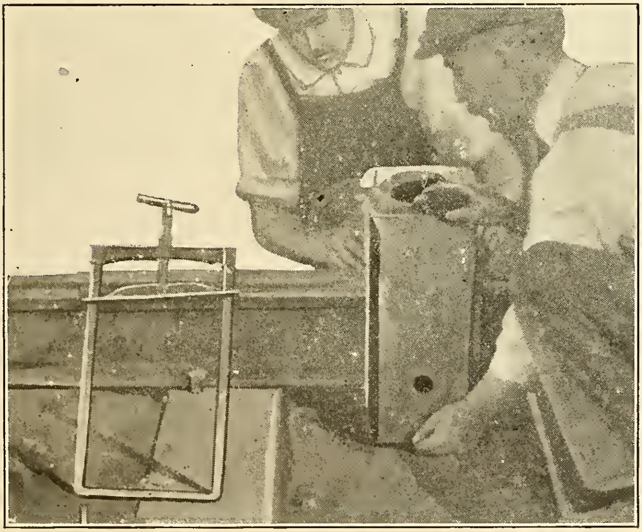


Fig. 54.—Adjusting Two-Part Mold to Rails.

in the center of the web. A squeezing machine being used for this purpose is shown in Figs. 55 and 56.

The pattern is so constructed as to form an opening around the rail ends in the shape of a collar into which the Thermit steel is poured. This collar is usually about 3 in. wide and

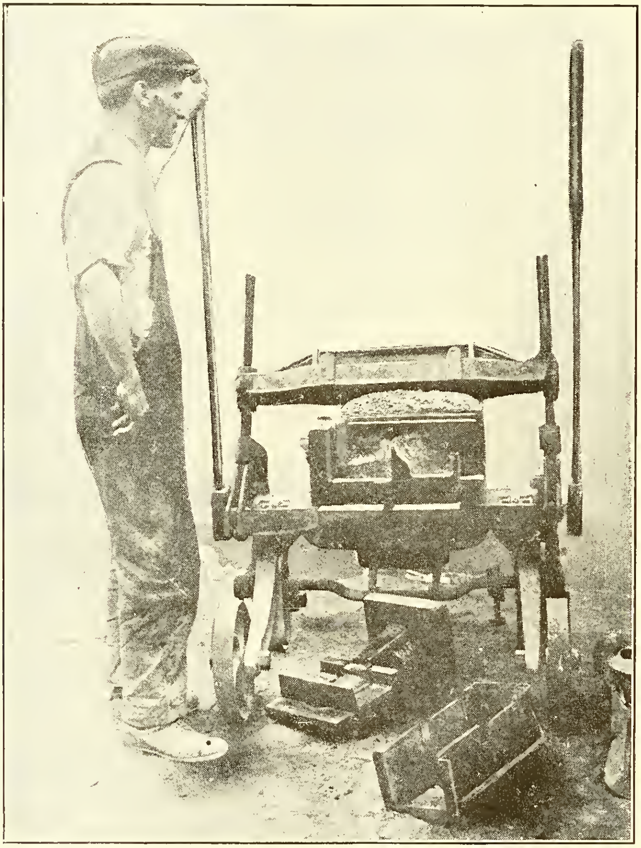


FIG. 55.—Ramming Molds on a Squeezing Machine. Wooden Patterns and Sheet-Iron Mold Box in Foreground.

varies from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. in thickness, depending on the rail section to be welded. Pouring gates and risers are also provided for in the mold in a similar manner to those already described.

Recent improvements in the construction of the molds used have been perfected to guard against runouts. A bead protrudes around certain parts, so that when the two halves are clamped together it is compressed between them and forms a safeguard against the liquid steel running out.

Before clamping the molds to the rails two cords of asbestos

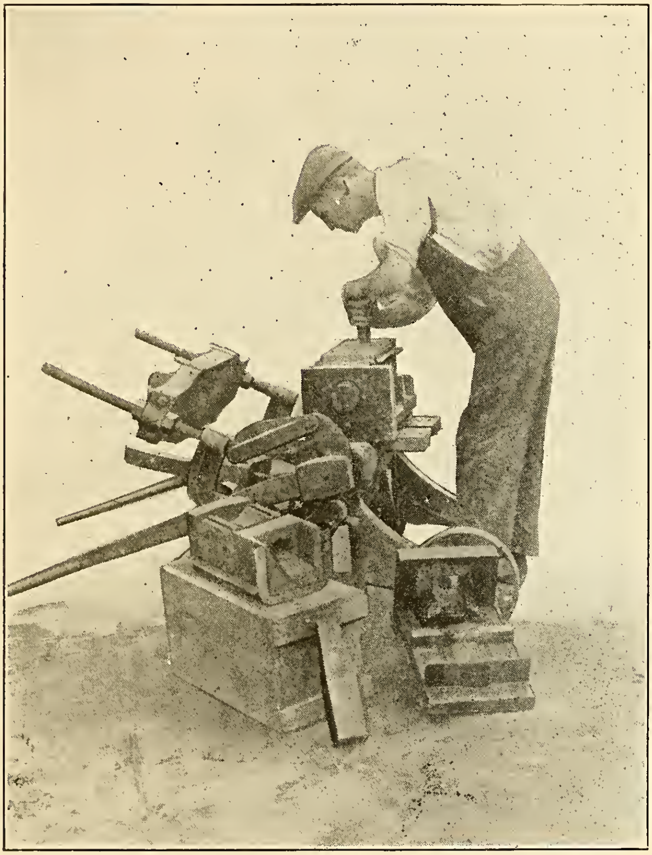


FIG. 56.—Cutting Heating Gate in Mold. Finished Mold and Wooden Pattern Shown in Foreground.

soaked in molasses are applied around the contour of the rail, one on each side of the joint, as shown in Fig. 57, and placed in such a position that they will come just inside the outer edge of the mold box. The molasses is sufficiently sticky to make these cords adhere tightly to the rail and form a very efficient luting all around the outside edge between the mold and the rail. As an additional precaution a small amount of fireclay is blown into the mold through the pouring gate by

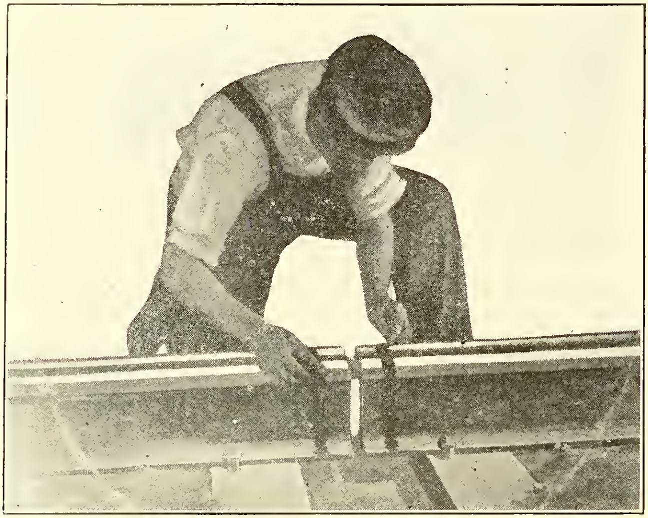


Fig. 57.—Applying Asbestos and Molasses Strips to Rails Previous to Placing Mold.

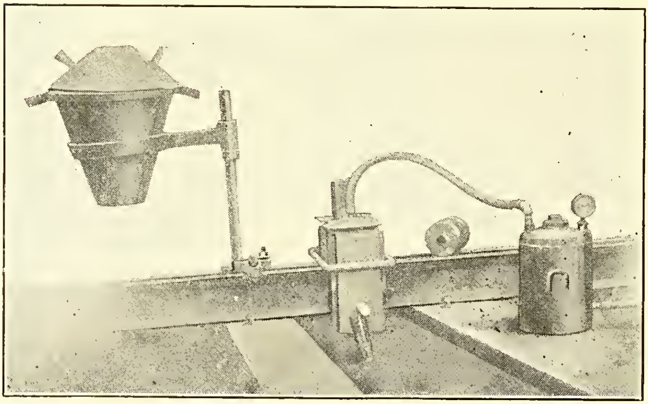


Fig. 58.—Final Luting Process, Blowing Powdered Fire Clay into the Mold.

means of compressed air, as shown in Fig. 58, while the other openings are closed temporarily by inserting wooden plugs. Should there be any opening around the edges of the mold the fire clay escaping through that opening will be caught by the molasses on the asbestos cords and the opening automatically sealed. When the air-pressure gage indicates that the mold is tight the wooden plugs are removed and all surplus fire clay blown out through a small blowout gate provided in the lower part of the mold.

Preheating.—The rails are now ready for preheating, and must be brought to a bright-red heat. For this purpose a special portable heater is used.

The opening in the mold through which the rails are heated

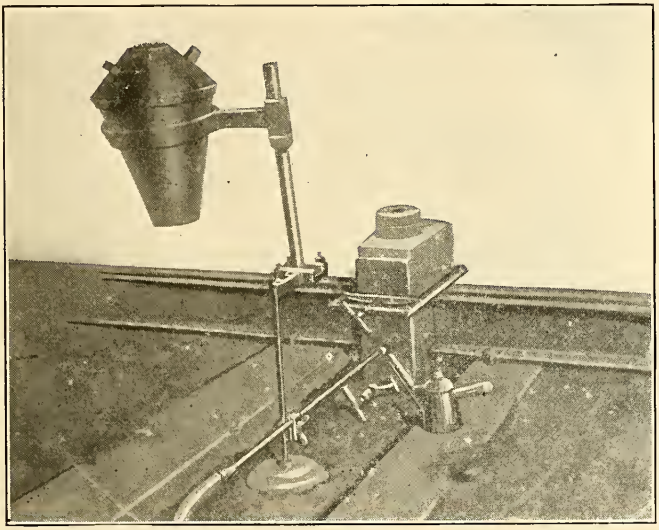


Fig. 59.—Mold and Crucible Clamped in Position Ready for Preheating. Box Containing Additions Set in Riser of Mold.

is situated about two-thirds from the top, so that the flame strikes the lower portion of the web of the rail and has the effect of heating the entire rail section uniformly. This preheating also accomplishes two other objects, as it bakes the mold and at the same time heats up a can of additions which are added to the Thermit in the crucible to improve the quality of the steel produced. This can of additions is placed on top of the mold in a special receptacle provided for the purpose in the riser opening, as shown in Fig. 59. As soon as the rails are red hot, the mold thoroughly dried, and the can of additions heated to the proper temperature, the burner is withdrawn and the heating gate plugged with a sand core. The burner is then directed down the pouring gate in order to restore any heat that may have been lost during the plugging operation.

The mold is now ready for pouring, and the crucible is placed in position, the reaction started and the melt tapped, just as described for other work of this character.

The steel enters the mold on the lip side of the rail and thoroughly melts and amalgamates with the lip as well as with

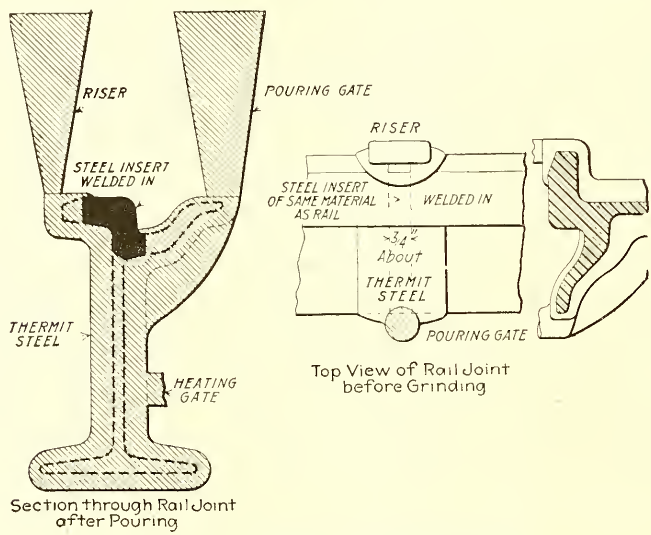


Fig. 60.—Sectional View of Rail Weld.

the web, base and one side of the head. No Thermit steel is allowed to touch the running surface of the rail, as the steel insert closes up the space between the rail ends except for a small opening of about $\frac{1}{4}$ in. from the outside of the head. The under part of the insert is thoroughly fused with the liquid steel and becomes a part of the fusion weld, as shown in Fig. 60.

As explained previously, when the metal in the weld begins to cool it produces sufficient pressure on each side of the insert, due to contraction, to thoroughly butt weld it in position so that at the end of the operation the entire rail is welded into one homogeneous mass. A finished weld is shown in Fig. 61 and in Fig. 62 is shown a number of operations going on at once.

One of the principal advantages of this type of weld is

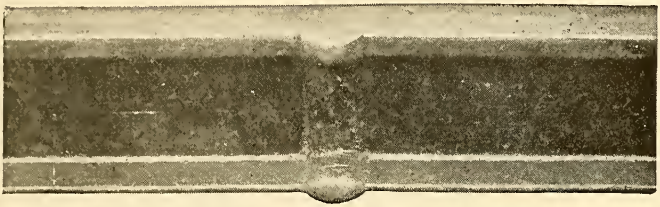


Fig. 61.—Finished Thermit Fully Welded Insert Joint.

that it depends on a predetermined chemical reaction which is always uniform. The success of the reaction is assured by the fact that every Thermit-welding portion is weighed out

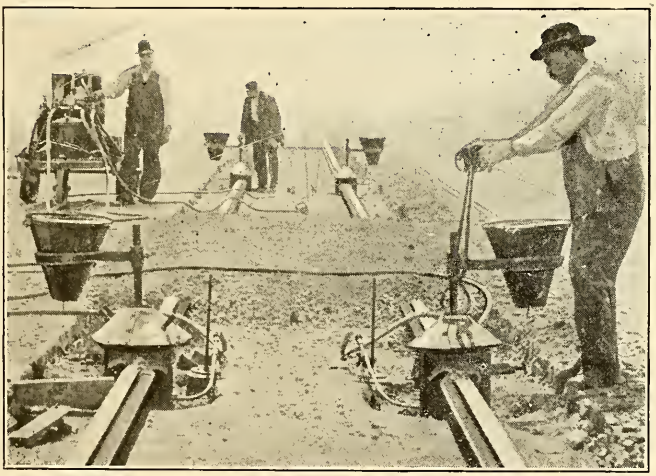


Fig. 62.—Preheating Rails, Drying Molds and Heating Thermit Additions, All in One Operation, Four Joints Being Heated at Once.

separately for each rail section to be welded and in just the proper quantity to obtain a perfect weld on that section.

The placing of the additions in a sheet-iron container is a fairly recent improvement and has resulted in not only obtaining a higher grade of steel in the weld than was possible formerly but also permits of obtaining a greater quantity of steel from the Thermit used. This in turn permits a weld to be made with less Thermit than formerly and has considerably reduced the expense of the welded joints.

THE USE OF ADDITIONS

The scheme of employing the additions as outlined is to use plain Thermit, and instead of mixing the additions of manganese, nickel and other materials for improving the quality of the Thermit steel throughout the Thermit itself these additions are now put up in the sheet-iron container which is placed on top of the mold during the preheating and is heated red hot by the waste gases. It is then placed in the center of the crucible and is melted down by the heat of the Thermit reaction.

This method enables the production of more steel from a given amount of Thermit without any sacrifice of heat, with the result that the cost of the welding portion of Thermit is considerably reduced.

After the weld has been poured *the mold should be left undisturbed for a few hours;* in fact, the longer it is allowed to cool the better, as the metal in the weld has time to become properly annealed. The mold boxes can then be removed, the metal left in the risers and pouring gates cut off by nicking with a hammer and chisel and knocking off. All sand, etc., is cleaned from the rail in the vicinity of the mold and the joint is ready for grinding.

The Grinding Machine.—As the steel insert is left a trifle higher than the rail section this excess metal must be ground off together with the excess metal left in the groove and on the outside of the head where the riser is removed.

This grinding can best be accomplished by means of the machine shown in Fig. 63. It possesses the advantage that the weight is concentrated over the grinding wheels so that a deeper cut can be taken. It also has attachments permitting of grinding in the groove of the rail and on the gage. If only a very few joints are being welded, however, the grinding can be very satisfactorily accomplished with a flexible-shaft grinding machine. In fact one of the great advantages of the Thermit process of rail welding is that a few joints can be welded almost as economically as a large number, and traction companies can do the work themselves wherever they please, and when the work is properly organized a gang of nine men can weld from 35 to 40 joints in a nine-hour day.

The simple and portable character of the welding outfit, including the grinding machine, is a strong point of merit, as one service car will carry all the equipment or it can be hauled on its own wheels.

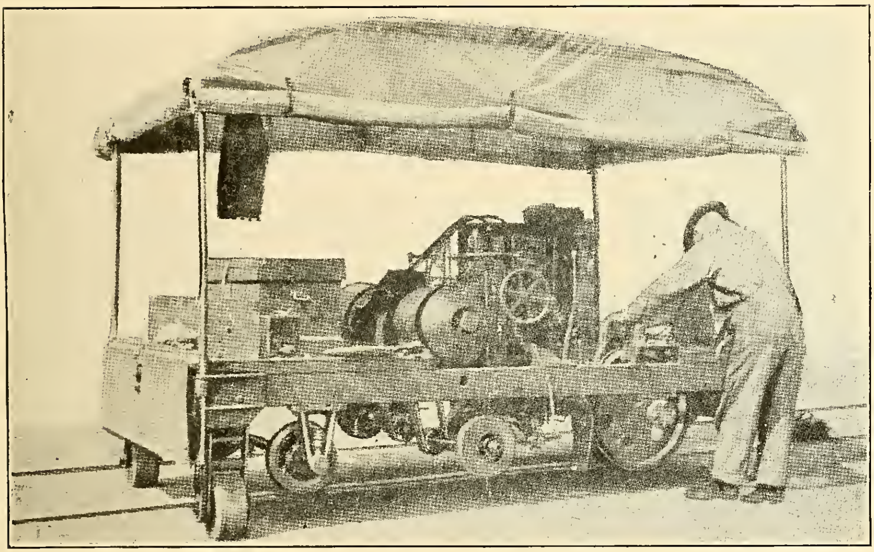


FIG. 63.—Rail-Grinding Machine Derailed Under Its Own Power.

The rail-grinding machine referred to was originally designed by the Thermit company for grinding Thermit-welded rail joints, but has proved very efficient for grinding out corrugations, pounded joints, and in fact anything that is required for a rail-grinding machine on an electric-railway system. An important feature is the derailing device which permits the removal of the machine from the path of traffic very quickly. The concentration of the weight over the grinding wheels has already been mentioned. By this arrangement deep or light cuts may be taken without danger of the grinding wheels chattering. The truck frame carries two axles.

One axle is fitted with ordinary 22-in. car wheels and the other has eccentrically mounted 13-in. wheels. By means of sliding adjustments the wheels may be spaced on their axles to fit road gages of from 4 ft. $8\frac{1}{2}$ in. to 5 ft. $2\frac{1}{2}$ in. The grinding-wheel brackets have both vertical and horizontal movement to allow for adjustment to the work. The bracket also may be rotated so that the face of the grinding wheel may be adjusted to the surface to be ground. By a special arrangement of the motors used the machine can be driven forward at a rate of 2 or 4 ft. per minute and 6 to 12 ft. per minute on the return. A reversing switch permits speeds to be used in either direction.

Where it is desired to grind out a depression a special arrangement is used by which an accurate curve is obtained. The grinding wheels run about 1833 r.p.m., which corresponds to a peripheral speed of 6719 ft. per minute on a new 14-in. wheel. The grinding-wheel motors are rated at $3\frac{1}{2}$ hp. and the propelling motor at $1\frac{3}{4}$ hp., and they are designed to operate on 500 to 550 volts. The derailing device operates by power and is quickly brought into use. The complete machine weighs about 6000 pounds.

CHAPTER VII

WELDING COMPROMISE RAIL JOINTS

There is very often a demand for a compromise joint to be supplied quickly when some bolted or cast-welded joint has failed. An inexpensive shop-welding outfit enables traction companies to weld their own compromise joints in a few hours, and these will give the same results in service as a regular Thermit rail weld.

When a large number of compromise joints are to be made on the same rail section it is advisable to have patterns and mold boxes made especially for the purpose. Where only two or three are to be welded, however, the work can be done by the "wax method," which is the method used in all general repair work. To assist in the aligning and surfacing of the rails when two short lengths are to be welded together it is advisable to provide a suitable bed to which the rails can be bolted. Two stringers running about 10 in.×6 in.×10 ft. long, on which four wooden or steel ties can be bolted, answer this purpose very well. The two center ties should be spaced about 18 in. in the clear and the second tie spaced to take care of the shortest length of rail to be welded. It is best to imbed the surfacing bed in the ground up to the top of the stringer. To hold the rails to the ties long bolts can be used in place of track spikes. These bolts should be allowed to project through the face of the tie a sufficient amount to take the smaller of the two rails. Allowance must also be made for a U-clamp, or bridge clip, one end of which will bear on the base of the rail and the other on the tie, or in the case of a small rail, will rest on a spacing block.

To bring the smaller rail up to the surface of the high rail a filling block is placed under the base, and to obtain accurate surfacing, shims or old hack-saw blades may be used in addition. With the rails spaced $\frac{3}{4}$ in. apart and accurately adjusted, the U-clamps are bolted down tight and the insert fitted as described for making ordinary rail welds. If patterns and mold boxes have been provided in advance the work proceeds in the same way as for ordinary rail welding, but if the wax method is to be used about 3 lb. of wax should be broken into small pieces, placed in a pan and heated until entirely melted. The wax is then allowed to cool until it becomes plastic. It may then be shaped by hand around the rail ends in the form of a collar.

USING A RAIL SECTION FOR A PATTERN

In cases where five or six compromise joints are to be welded between the same rail sections considerable time and trouble can be saved by using a short length of each rail section as a pattern. These should be about 8 in. long, butted together and fastened by tacking with the oxy-acetylene-welding process so that they will be held together securely. Mold boxes of sheet iron in two halves can be cut to fit with the oxy-acetylene cutting flame so that they will fit the sections to approximately $^1/_{16}$ in. all around. Each half of the mold box will then have a different section cut in each side. A wax collar is formed around the joint of the two pieces of rail in the regular way as described above and the one-half of the mold box is laid on the ground back down, placing the pattern made by tacking the two rail sections together on this half of the mold box. Then thin pieces of sheet iron are laid on top of this half to obtain a parting when the other half of the mold box is placed on top. The other half may then be placed in position and rammed up to the height of the riser with molding material, using a wooden pattern for the riser opening. When this has been completed the whole mold box, pattern and all, is turned over and the bottom half of the mold box rammed, inserting a wooden riser pattern in a similar way to the first half. This bottom half is then rapped slightly and lifted from the pattern. Then by rapping the pattern it may be lifted from the other half of the mold box. After removing the riser pattern the molds are ready to be placed on the rails to be welded, but before doing so the space between the lip and the ball of those rail sections should be rammed flush with molding material. When the boxes are adjusted they should be luted carefully with fireclay around the outside edges between the mold and the rail to guard

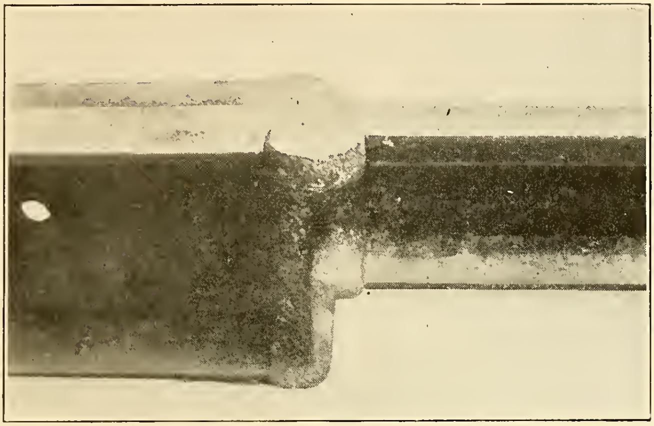


Fig. 64.—Welded Compromise Joint Between T-Rail and Grooved Rail.

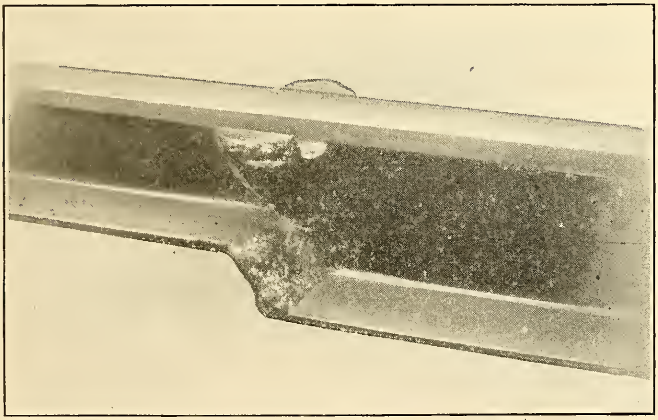


Fig. 65.—Welded Compromise Joint Between Two T-Rails, Showing False Lip.

against any run out of Thermit steel. The joint can then be preheated and poured in the regular way.

This method will be found to save considerable time over waxing each joint separately, and the two short-rail sections can be used as a pattern for any number of molds. If both right-hand and left-hand compromise joints are required the same pattern and mold boxes can be used by simply disconnecting and rearranging for either right or left. A welded compromise joint between a grooved and a T-rail is shown in Fig. 64.

Where a compromise joint is to be welded between two T-rails as shown in Fig. 65 the same method can be used except that in this case it is necessary to arrange for a false lip to be cast out of Thermit steel similar to the lip of a grooved rail. In other words the Thermit-steel collar must be carried around each side of the head and on one side must be shaped in a corresponding manner to the lip of a groove rail. This is necessary because when the metal begins to cool and contract there must be an equal shrinkage force on each side of the insert extending to the top of the head tending to draw the rails together, otherwise the insert will not be thoroughly butt-welded into the head.

THE CLARK JOINT

Shortly after the development of the Thermit rail-welding process, Charles H. Clark, chief engineer of the Cleveland

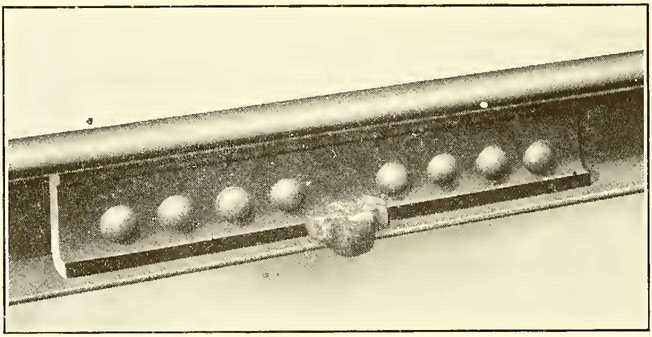


Fig. 66.—Completed Clark Joint.

Railway Co., perfected a joint known as the "Clark joint," which has proved exceedingly successful in Cleveland and other Eastern cities where many thousand joints have been installed.

In its original form it consisted of a combination of splice bars and Thermit steel, it being Mr. Clark's opinion that the head of the rail could be supported by using plates that would

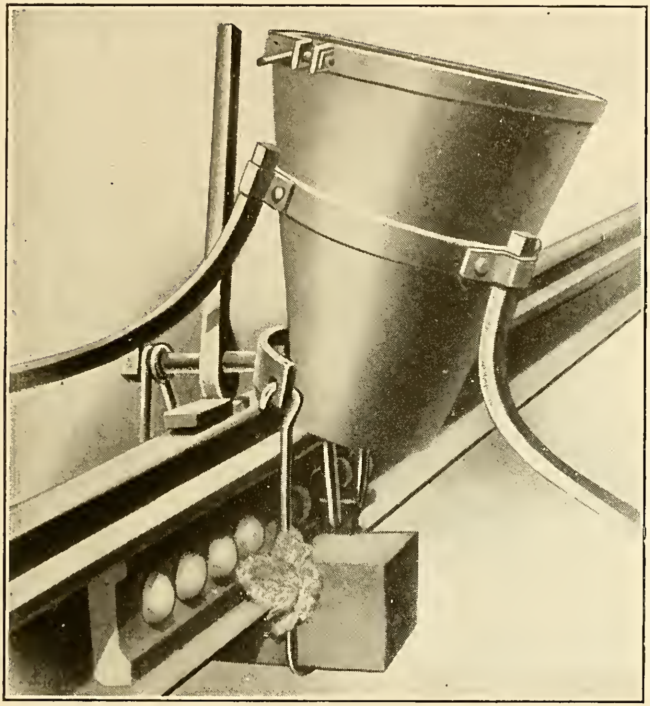


FIG. 67.—Open Mold and Crucible in Position for Making Clark Joint.

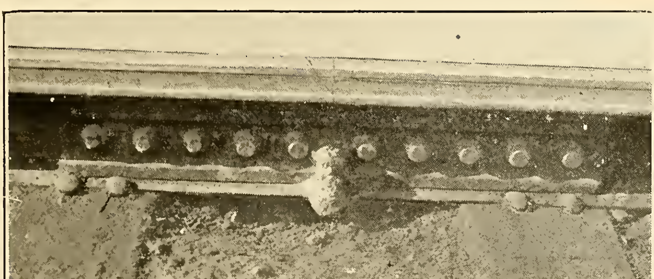


FIG. 68.—Completed Modified Clark Joint, Showing Weld of Base.

come under the ball of the rail. Furthermore, in order to hold the rail rigid he considered it important that there should be no play in the bolts, so the holes in the plates and rails were drilled round and machine bolts used after reaming for a drive fit. In order to keep the bolts and plates from working loose and to afford bonding between the rails a Thermit-steel shoe was cast around the base as shown in Fig. 66.

In practice the rails and splice bars are drilled with holes $^1/_{16}$ in. less in diameter than the bolt to be used. The splice

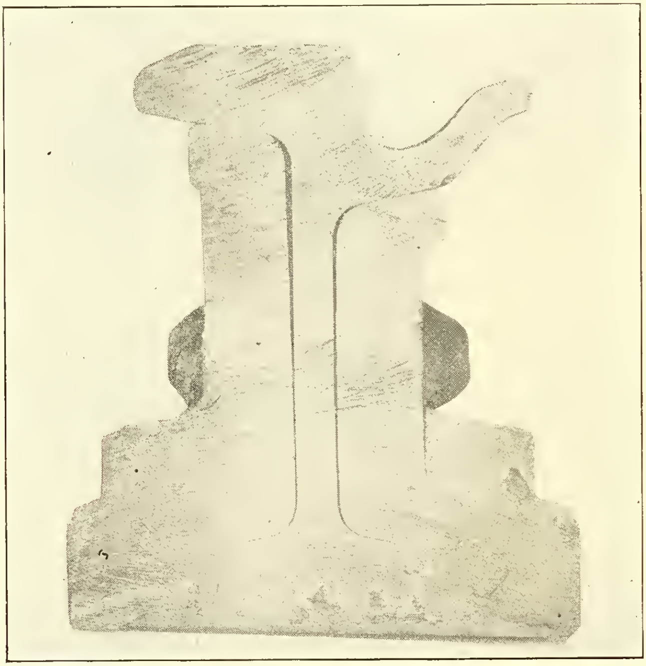


FIG. 69.—Section through Modified Clark Joint. It will be Noticed that the Lower Part of the Rail and Fish Plates are entirely Amalgamated.

bar is then applied in the ordinary way and held in place by a couple of temporary bolts, a drift pin being driven into one hole each side of the joint to keep the rails in position. The remaining holes are then reamed with straight-end cutting reamers, after which the machined bolts are driven and tightened up in the usual manner. After preheating the rail ends the Thermit steel is run into an open mold surrounding the lower part of the rails as illustrated in Fig. 67.

In the latest type of Clark joint rivets are substituted for the machined bolts, the riveting being accomplished by a pneumatic riveter suspended from the rear end of a flat car carrying an air compressor.

A modification of the Clark joint, shown in Fig. 68, has been adopted with marked success by the United Railways and Electric Co., Baltimore, and is also being used on other properties.

The object of the modification was to obtain a larger weld

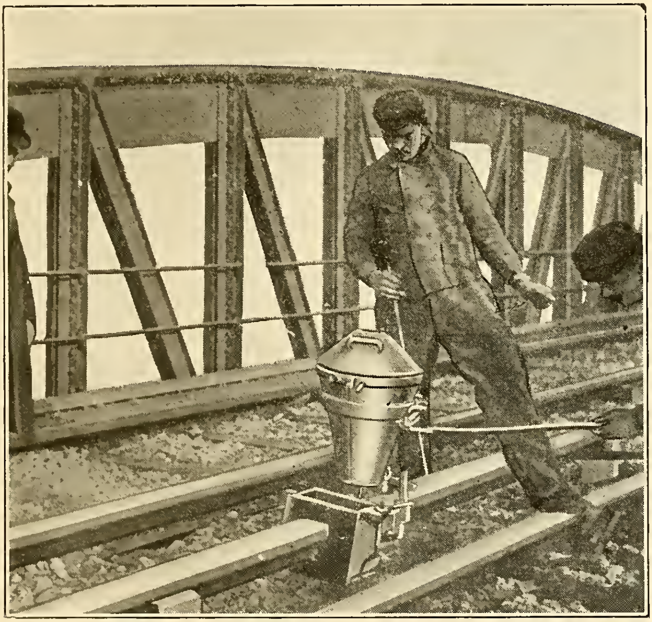


FIG. 70.—Appliances in Position for Welding Third Rail.

of the base, and in order to do this the Thermit steel was poured into an inclosed mold box instead of into an open mold and the rail ends were preheated to a red heat with the molds in place before the Thermit charge was ignited. Furthermore, the design of the fish plates is somewhat changed, these being of special design 1 in. in thickness and 32 in. long and being so formed as to fit snugly the contour of the head and base of the rail. At the same time they provide a minimum amount of space between the web of the rail and the vertical sides of the fish plates. The channel bars and rails are of the same kind of steel (high carbon) and both are punched at the mill with ten $1^1/_{16}$-in. holes, spaced 3 in. centers and beginning 2 in. from the end of the rail.

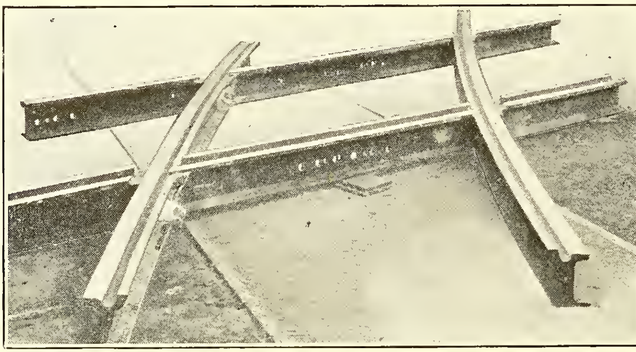


Fig. 71.—A Welded-Up Cross-Over.

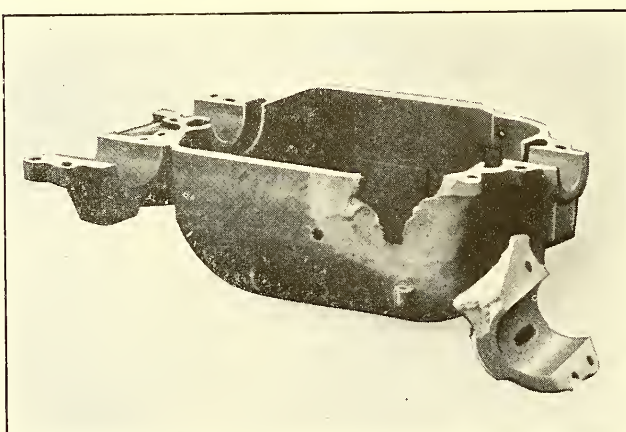


Fig. 72.—Motor Case with Broken Lug Previous to Welding.

The joint has been applied thus far exclusively for 7-in. girder groove rails weighing 103 lb. per yard. These 7-in. girder sections are undercut by the manufacturers $^1/_{16}$ in. so as to provide a space of $\frac{1}{8}$ in. at the base when the rail heads are butted. This procedure more effectively enables the

Thermit steel to weld the rail and fish plates into a solid mass at the joints, as shown in the section, Fig. 69.

Welding the Third, or Conductor, Rail.—The welding of the third rail has been carried on more extensively abroad than in the United States. This is especially true of France, where several thousand joints have been welded for the Metropolitan Railway and others in the neighborhood of Paris where this method of bonding is now standard practice.

In making these welds in France the base and flange only of the rail was welded with Thermit steel.

As a great deal of third rail, both here and abroad, is used

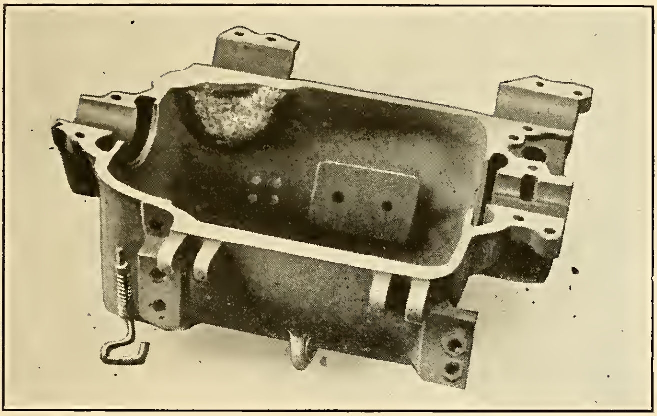


FIG. 73.—Motor Case Welded and Ready for Service.

in tunnels and subways, it is not necessary to make any provision in such cases for expansion and contraction, it having been found from practical experience that the temperature changes seldom exceed 25 or 26 deg. F. These are the figures that were determined by experiment in the subways controlled by the Metropolitan Railway of Paris. In cases, however, where the third rail is laid in open stretches of track where it will come under the full influence of atmospheric changes in temperature it is of course necessary to provide suitable means for taking care of the expansion and contraction, and this can be easily done by installing an expansion joint at regular intervals.

Welding third rails has advantages that need hardly be enlarged upon, providing, as it does, for a uniform electrical conductivity of the rail in question and a method of bonding which will not deteriorate.

A Thermit outfit in position for welding a third rail is shown in Fig. 70.

A very simple way to make cross-overs of any desired form is shown in Fig. 71. The rails are cut, shaped and then Thermit welded together and then the surfaces are ground.

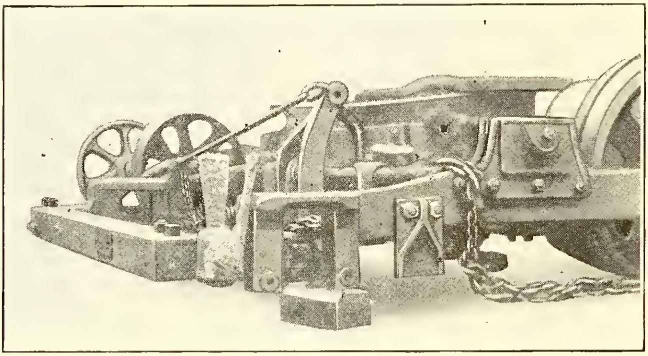


FIG. 74.—Weld on Broken Truck Frame.

The result is as smooth and solid a cross-over as it is possible to make. This is suggestive of many other similar uses.

The same outfit required for welding compromise joints can be used most advantageously for welding motor cases and truck frames. The process offers special advantages for such repairs, owing to the fact that the collar, or reinforcement of Thermit steel, which is fused around the weld may be made heavy enough to insure against future breakage.

In Fig. 72 is shown a broken motor case, and in Fig. 73 a welded one. A welded truck frame is shown in Fig. 74.

CHAPTER VIII

WELDING CAST IRON AND OTHER PARTS

The Thermit process, while adapted to the welding of cast iron, cannot be used on all cast-iron welds owing to the difficulty in many cases of allowing properly for the shrinkage of the metal in the weld when cooling. The Thermit steel contracts twice as much as the cast iron, so that in certain constructions shrinkage strains will be set up in the weld causing cracks. This difference in shrinkage often makes it impractical to weld long cracks in thin sections. As a general rule we should say that if the length of crack is more than eight times the thickness of the material a Thermit weld should not be attempted, because on account of the difference in shrinkage along the line of the fracture small hair-line cracks will appear perpendicular to the line of the fracture. These cracks, however, being perpendicular to the line of the weld are often therefore of little consequence and do not interfere with the strength of the weld.

It is also not usually feasible to weld cracks in cast-iron cylinders, pots, kettles and similar castings. Where there is a clean break between two sections or where the section to be welded can be completely cut through and can be separated a sufficient amount to allow for the contraction in the weld, and also where the length of the weld is not more than eight times the thickness of the material, a Thermit weld would be entirely practical and can be made in exactly the same way as outlined for the welding of wrought-iron and steel sections.

In cases where the crack can be opened up mechanically or by heating a parallel part to a dull red a weld may be made, but it must be remembered that expansion gained in this way must be a little more than the expansion of the parts next to the weld during the preheating.

Care should be taken in preheating for cast-iron welds not to heat the sections too hot; a dull red is sufficient. One should be careful to keep the heat going until the mold is thoroughly dried out.

The mixture of Thermit for the weld should be different than for wrought iron and steel, and for this purpose the special mixture known as cast-iron Thermit is recommended. This consists of plain Thermit with which is mixed 3 per cent ferrosilicon and 20 per cent mild-steel punchings, i.e., to every 100 lb. of plain Thermit is added 3 lb. of ferrosilicon and 20 lb. of punchings. This gives the best results on cast iron and produces a homogeneous metal in the weld.

Welds on cast iron are a little more difficult to machine than welds on wrought iron and steel, as the metal along the line of junction of the Thermit metal and the cast iron is apt to be a trifle hard due to the absorption of carbon from the cast iron. This objection is not a serious one, however, and hundreds of welds have been completed with the most satisfactory results.

Examples of Cast-Iron Welds.—In order to show the possibilities of welding various cast-iron pieces with Thermit a few examples taken from actual practice are given.

Fig. 75 shows how a new jaw was burned onto the frame of a heavy shear, in the shops of the Raleigh Iron Works Co., Raleigh, N. C. The job was done in 1906 and the machine is still in service. This machine was designed for shearing $1\frac{1}{2}\times 6$-in. bars, producing an enormous strain on the jaws. A large part of the corner of the lower jaw, weighing about 75 lb., broke off. It then became a question of getting a new frame or burning on a new jaw corner, which would require the fusing of a surface about 1 sq. ft. in area in order to obtain a thorough union. It was finally decided to try Thermit. The surface of the break was chiseled off for the reason that a cast-iron break is usually glazed with graphitic carbon. The mold was then put in place and well luted with fire clay where there was any danger of leakage. Moist sand was also rammed around the mold and other parts as a further precaution. The surface of the fracture and the stock around the jaw was then heated through the gates and risers by means of gas jets, in order that the casting might be thoroughly heated and all moisture driven out. The gas torches were kept in action several hours. A crucible containing 175 lb. of Thermit was then put in position for tapping into the mold. After the reaction the Thermit steel was run into the mold and at once fused the entire surface of the fracture. In the meantime a

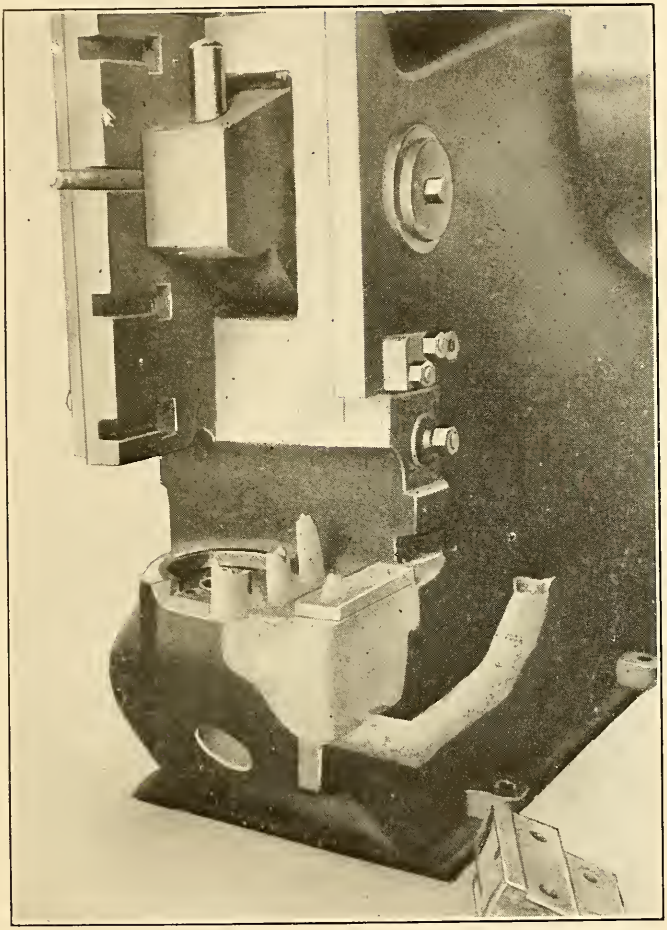


FIG. 75.—New Jaw Burned to Frame Casting of Heavy Shear.

ladle of molten cast iron containing about 600 lb. of metal was held in readiness and was superheated by means of a Thermit semi-steel can. As soon as possible after pouring the Thermit, this cast iron was poured into the second gate, shown at the front of the jaw, and this forced the Thermit steel out of the mold after it had served its purpose in bringing the surface of the jaw to a welding or fusing heat. The result was a new corner of cast iron burned onto the old jaw. The illustration shows the two gates and four risers before they were trimmed off. In *Reactions* for the fourth quarter of 1917 W. J. Musick, blacksmith foreman of the St. Louis shops of the Missouri Pacific R.R. wrote:

> We recently had one of our steam hammers break through both sides of the frame and through the throat, the fracture being 61 in. long. This hammer was so badly broken that it seemed as though it were doomed for the scrap pile.
>
> A new steam hammer was ordered, but in the meantime it was decided to try to repair the old one with Thermit. The weld was made and a successful repair was accomplished, resulting in saving a considerable amount of money.
>
> We have also welded a cast-iron engine bed for the Helmbacher Rolling Mill Co. The bed of this engine is 32 in. high and 12 in. across the top. The mill was only shut down 24 hours while the repair was being made.

Master Mechanic George M. Stone, writing in the same publication, says:

> I think your readers will be interested in the accompanying illustrations of Thermit welds which have been made by me in the shops of the Chicago, Rock Island and Pacific Railroad, Chickasha, Okla., and I would like to call particular attention to the welding of valve seats on locomotive cylinders, which I consider an exceptionally good piece of work in view of the fact that these are cast-iron cylinders. The manner in which we handled the work was as follows:
>
> The ports of the cylinders were cracked through from the steam port to the exhaust port. A Thermit weld was made on these cylinders, and in order to do this the entire cylinder was cut loose from the frame and smoke arch of the locomotive. The pistons were removed from the cylinders, as well as the cylinder heads both front and back. The cylinder was then preheated with a slow wood fire and welded with Thermit.
>
> We have also had very good success with the welding of spokes in driving-wheel centers and the welding of main frames on one of our heaviest classes of engines in freight service.

These instances show that in many cases the success or failure of a cast-iron welding job is merely a matter of good judgment. As in other kinds of welds, expansion and contraction must be allowed for, and in many cases where a purely

Thermit weld would be out of the question, owing to the difference in contraction of cast iron and Thermit steel, the Thermit may be used merely to bring the broken surface up to a fusing heat and then molten cast iron may be burned on, as was done with the shear jaw previously mentioned.

The illustrations here given show how Thermit welding may be applied to various cast-iron machine parts. Fig. 76

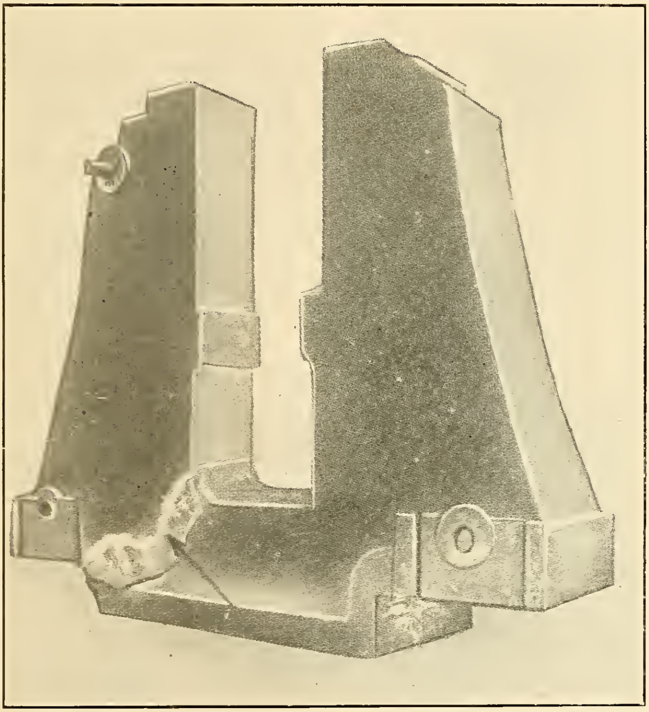


Fig. 76.—Weld on 48-In., 68 000-Lb., Cast Iron Blooming-Mill Housing. About 3500-Lb. of Railroad Thermit Used.

shows a weld on a 48-in. blooming mill housing, which weighed 68,000 lb. Approximately 3500 lb. of railroad Thermit was used. Fig. 77 shows a weld on a rolling-mill bed made for the Waclark Wire Co., Elizabeth, N. J. The weld shown in Fig. 78 was on a 25-ton nail-machine housing, and 650 lb. of Thermit was used. Another housing weld on a knuckle machine made by the Standard Parts Co., Cleveland, is shown in Fig.

79. Many times breaks on machine-tool parts could be repaired in the same way.

Welding High-Speed Steel to Machinery Steel.—The largest weld ever made, up to January, 1919, was a cast-iron weld on a blooming-mill shear at the plant of the Pittsburgh Steel

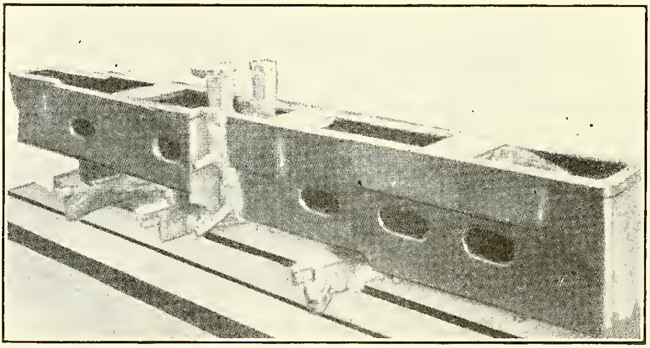


FIG. 77.—Cast-Iron Rolling Mill Base Repaired for the Waclark Wire Co., Elizabeth, N. J.

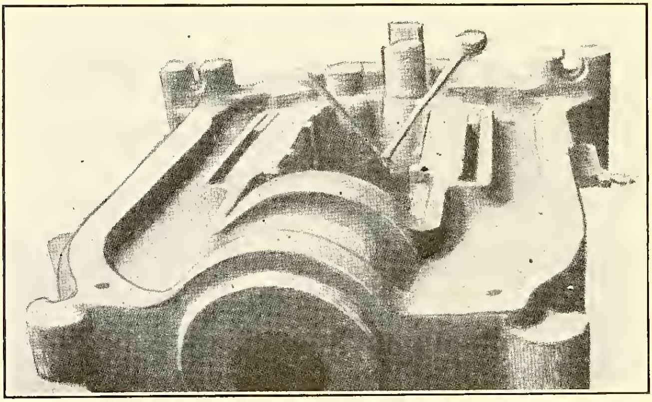


FIG. 78.—Repair on a 25-Ton Nail-Machine Housing.

Co. The broken piece was of irregular shape approximately 37 in. wide by 5 ft. 6 in. long and weighed about 3000 lb. Five No. 10 crucibles were used for the job.

Sometimes it is advisable to weld tool or high-speed steel to a mild-steel bar or shank. This is perfectly feasible for special drills, reamers, boring bars or special tools of various kinds. Where only one or two jobs are to be done ordinary welding by the wax-core method may be employed, but where many pieces are to be welded it will pay to make molds. A

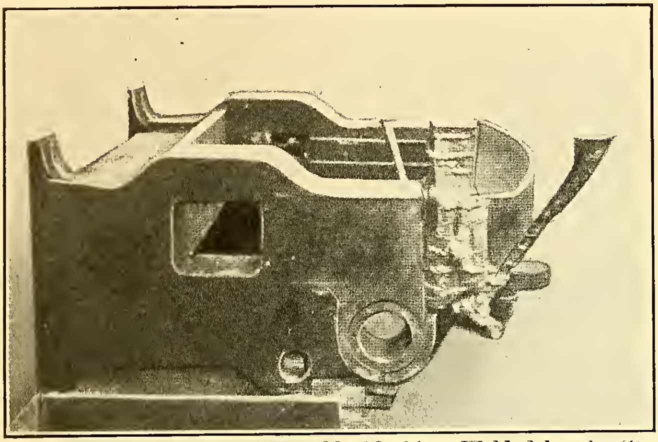


FIG. 79.—Cast-Iron Housing of Knuckle Machine, Welded by the Standard Parts Co., Cleveland, Ohio.

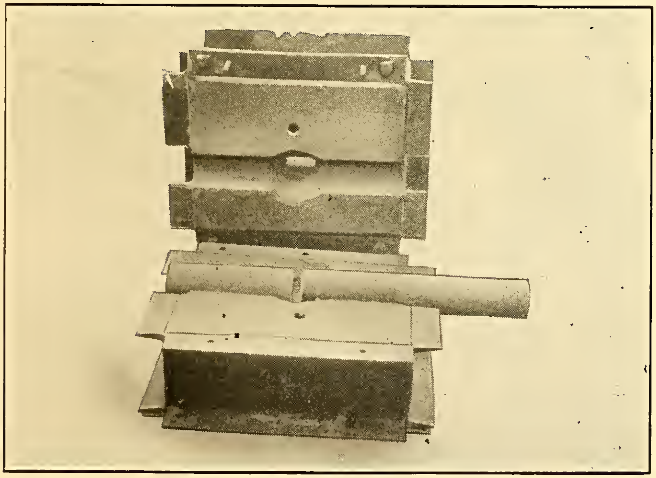


FIG. 80.—Machinery Steel and High-Speed Steel Ready to Clamp Mold.

mold for welding round bars together is shown in Fig. 80. The pattern and mold box for this are shown in Fig. 81.

High-speed steel blades may also be welded into large or emergency job reamers in a comparatively short time. For this purpose a cylinder is bored out slightly larger than the hole to be reamed. The blades for the reamer are placed inside this cylinder and wedged into their proper places. Tin or wooden spacing pieces may be used for this if they are so placed as to be removed after the wax hardens. After the blades are fixed in position another cylinder or piece of pipe is centered inside the blades, allowing space between the blades and this cylinder according to the size of the reamer being made. Wax is next poured into the spaces between the blades

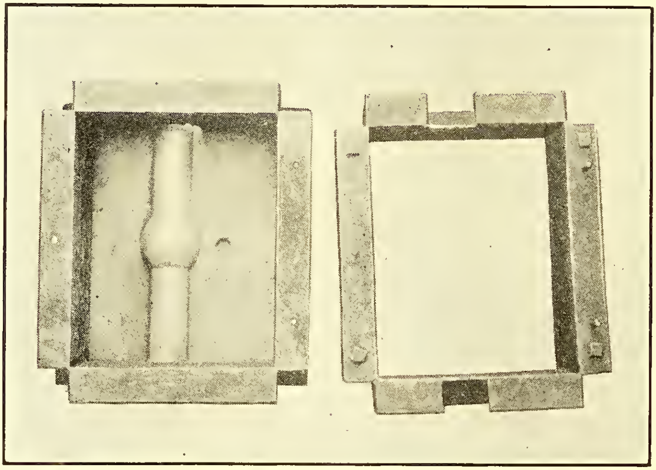


FIG. 81.—Sheet-Iron Mold Box and Wooden Pattern.

and the inner cylinder. After it is removed from the outer cylinder and the wax hardens, enough of it is trimmed away between the blades to allow for chip space. The wax matrix with the blades in place is then rammed up in a mold. The inner cylinder is then warmed slightly and removed. A steel shank is next inserted and centered correctly. The wax is now melted out and the Thermit steel run in, welding the blades securely to the steel shank. A wax matrix, with blades and inner cylinder in place, is shown in Fig. 82. In this illustration the wax has been cut away between the blades and the assembly is ready to be put into the mold box and be rammed up. When the work is cool it is centered and the blades ground for size and clearance.

A helical reamer with inserted high-speed steel blades is shown in Fig. 83. This reamer was made by T. O. Martin,

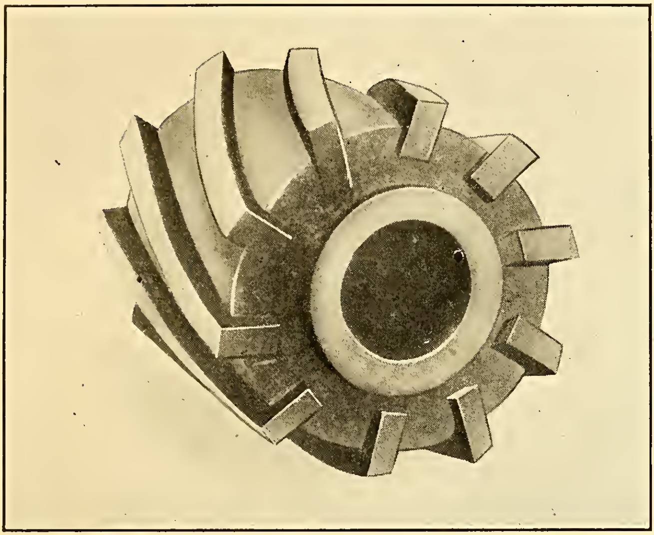


FIG. 82.—High-Speed Steel Cutters Held in Wax Pattern with Hollow Steel Core

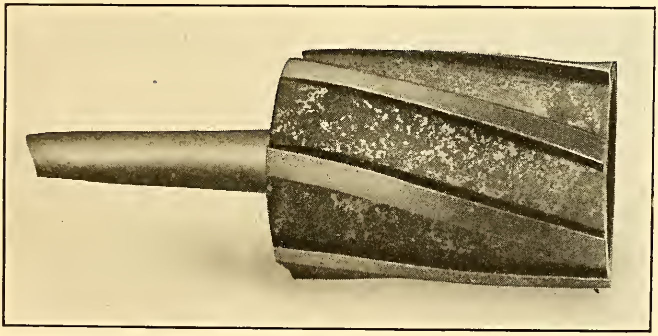


FIG. 83.—Helical Inserted-Blade Reamer Made by the Thermit Process.

blacksmith foreman of the Illinois Central R.R. shops at Jackson, Tenn.

Preheaters for Thermit Work.—As practically all welds in ordinary practice, except those on pipe, require preheating it is well to use heaters made for the purpose wherever possible. In some shops gas-burning torches supplied with compressed air may be used. Many shops, however, have neither gas torches nor compressed air. This method is not practicable on outdoor welds. Crude-oil heaters should not be used at all, on account of their tendency to deposit carbon or other matter on the surfaces to be welded, thereby causing imperfect welds. In order to make the preheating work as easy and convenient as possible the Metal and Thermit Corporation makes the preheaters here shown. Fig. 84 shows two kinds, a single and a double burner. For infrequent or small jobs the single burner, which may be fitted with a flaming burner also, will probably answer the purpose. Where a number of

TABLE V.—COST OF THERMIT AND APPARATUS FOR GENERAL WELDING

	Gross Lb. Shipping Weight	Cost
Railroad Thermit (50-lb. boxes only)	67½	$17.50
Plain Thermit (50-lb. boxes only)	59	17.00
Cast-iron Thermit (50-lb. boxes only)	70½	17.50
Ignition powder (½-lb. cans)	..	.45
Yellow wax, per pound	..	.35
Punchings, per pound	..	.025
Special molding material (300 lb.)	340	4.00
Fire clay (300 lb. net)	340	3.50
Fire brick, per barrel (300 lb. net)	340	4.00
Kiln-dried silica sand (300 lb. net)	340	3.50
Single-burner preheater	200	50.00
Double-burner preheater	225	75.00
Flaming-burner attachment	...	3.00
Magnesia stones, No. 1	...	.15
Magnesia stones, No. 3	...	.20
Magnesia thimbles, No. 1	...	.10
Magnesia thimbles, No. 3	...	.15
Magnesia tar, about 400 lb. net	450	.06
Plugging material, No. 2 package	...	.10
Automatic crucibles (with caps and rings)	40	4.00
Automatic crucible, No. 2	60	5.50
Automatic crucible, No. 5	150	11.00
Automatic crucible, No. 10	775	60.00
Cast-iron relining cone, No. 1	50	5.00
Cast-iron relining cone, No. 5	150	12.00
Cast-iron relining cone, No. 10	600	40.00
Tripods, Nos. 1 to 7, weights 11 to 65 lb.	...	$2.50 to 9.00

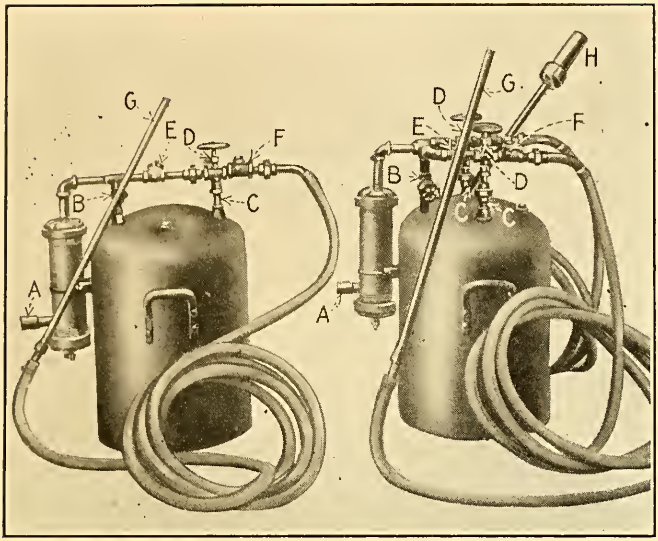


FIG. 84.—Single-Burner and Double-Burner Preheaters, Using Either Gasoline or Kerosene.

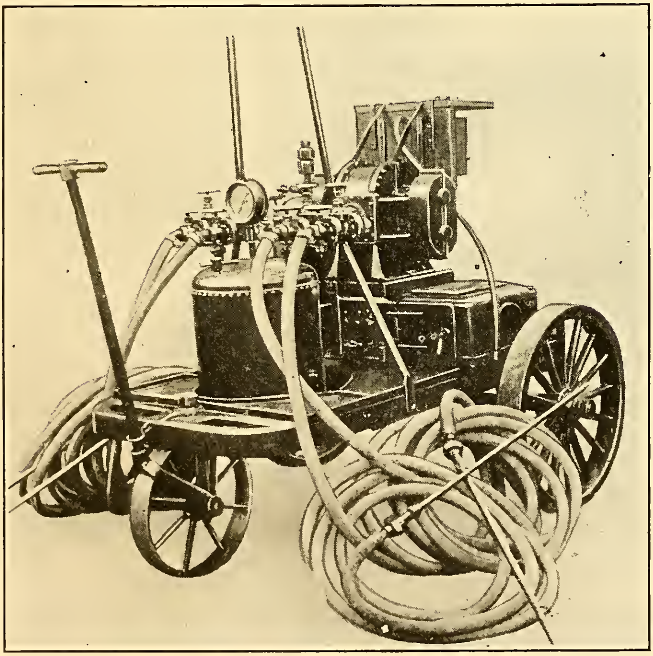


FIG. 85.—Rail Preheater That Will Heat Four Joints at Once.

welds are to be made, however, the double-burner apparatus should be selected. In these illustrations *A* is the place to attach the hose from the compressed-air supply; *B* is the valve for regulating the pressure on the surface of the fuel; *C* is a tube which runs within a few inches of the bottom of the tank; *D* is the needle valve which controls the fuel to the burner; *E* is the air pressure control to the burner; *F* is a check valve which prevents back fire; *G* are torches or burner pipes; *H* is a flaming burner. The small tank on the left side is a water separator for the compressed-air supply.

Table VI.—Cost of Materials and Appliances for Pipe Welding Standard Weight Pipe.

Inside Diameter, Inches	Price of Welding Portions: 100 or Less	Over 100 and Less than 500	Over 500 and Less than 1000	1000 or More	Price of Mold	Price and Size of Crucibles	Price and Size of Tongs	Price and Size of Clamps	Price and Size of Pipe Facing Machines
½	$0.36	$0.32	$0.27	$0.19	$0.75	No. 2	No. 2	No. 1	No. 1
¾	.44	.40	.36	.26	.75	2	2	1	1
1	.60	.56	.55	.39	1.00	2	2	1	1
1¼	.78	.74	.69	.60	1.25	2 $1.75	2 $2.00	1	1 $35.00
1½	.90	.86	.84	.75	1.50	2	2	1 $20 00	1
2	1.03	.99	.97	.90	1.75	2	2	1	1
2½	1.50	1.46	1.43	1.35	2.00	3 3.00	3 2.50	1	1
3	2.16	2.12	2.09	2.06	2.25	3	3	1	1
3½	3.06	3.02	2.99	2.96	2.50	4 4.75	4 3.25	2 25.00	2 60.00
4	4.63	4.59	4.56	4.50	2.75	4	4	2	2
EXTRA HEAVY PIPE									
½	$0.45	$0.42	$0.37	$0.29	$0.75	2	2	1	1
¾	.54	.48	.42	.34	.75	2	2	1	1
1	.72	.67	.62	.56	1.00	2 $1.75	2 $2.00	1	1
1¼	.90	.86	.84	.75	1.25	2	2	1 $20.00	1 $35 00
1½	1.14	1.10	1.05	.98	1.50	2	2	1	1
2	1.78	1.75	1.71	1.65	1.75	3 3.00	3 2.50	1	1
2½	2.94	2.90	2.86	2.80	2.00	4	4	1	1
3	4.23	4.20	4.16	4.10	2.25	4 4 75	4 3.25	1	1
3½	5.43	5.40	5.36	5.10	2.50	4	4	2 25.00	2 60.00
4	6.22	6.18	6.14	6.08	2.75	5 7.50	5 4.50	2	2
DOUBLE EXTRA HEAVY PIPE									
½	$0.93	$0.90	$0.86	$0.81	$1.50	No. 2 $1.75	No. 2	No. 1	No. 1
¾	1.08	1.04	1.02	.96	1.75	2	2 $2.00	1	1
1	1.20	1.16	1.14	1.08	2.00	3 3.00	2	1	1
1¼	1.49	1.43	1.41	1.36	2.25	3	3 2.50	1	1
1½	2.14	2.08	2.03	1.94	2.50	4 4.75	3	1 $20.00	1 $35 00
2	3.82	3.73	3.71	3.68	2.75	4	4 3.25	1	1
2½	7.30	7.27	7.24	7.20	3.00	5 7.50	5 4.50	1	1
3	10.60	10.57	10.54	10.50	3.50	5	5	1	1

Fig. 85 shows a four-burner portable apparatus used largely for rail-welding work. It carries its own air compressor, which may be run by attaching to a trolley wire or to some other electric-current supply. All of these burners use either gasoline or kerosene.

Cost of Thermit Welds and Apparatus.—There are many factors which enter into the calculation of the cost of Thermit welding and the apparatus. Where a single weld is to be made and the shop man has to buy the apparatus, materials and do the work himself, the cost will naturally be higher than where several welds are to be made or where he can hire it done. There are so many places now making a specialty of Thermit welding that in ordinary circumstances it is usually better to have them do the work on large jobs than for inexperienced men to undertake the work.

Data for the appropriate cost of various jobs have been given in tables and specifications throughout the article, but in order to give those responsible for repair or other welding work, as exact information as possible on which to base their calculations, the accompanying tables are included. These are taken from the price list of the Metal and Thermit Corporation, published June 15, 1918, and of course are subject to changes. These quotations are f.o.b. Jersey City, N. J. Table V gives prices for general welding materials, and Table VI for pipe work. It will be noted that some of the quotations in this last table do not exactly agree with figures given in the table of comparative costs of Thermit welded and mechanically-joined pipe, but it should be borne in mind that the comparative table gives averages only, and is also subject to variations in cost of labor and materials.

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